W. B. No. 741

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

U. S. weather review

MONTHLY WEATHER REVIEW

VOLUME 49, No. 5

MAY, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

CORRIGENDA.

This REVIEW, April, 1921:

Page 200, 1st column, equation (1) *should read* "$P_e = \frac{44t\epsilon^{-t^{0.[illegible]}}}{60}$"

Page 200, 2nd column, 11th line of second article, "effected" *should read* "affected".

Page 201, equation (2), the exponent of *t* *should read* "0.635"; also likewise in the equation at top of page 202.

Page 203, 1st column, next to last paragraph, "5.3 times" *should read* "5.33 times".

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of contributions is not to be construed as official approval of the views expressed.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
SUPPLEMENT No. 3.

// MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

Vol. 49, No. 5.
W. B. No. 741.

MAY, 1921.

Closed July 1, 1921
Issued August 4, 1921

TEMPERATURE SURVEY OF THE SALT RIVER VALLEY, ARIZONA.

By James H. Gordon, Observer.

[Weather Bureau, Yuma, Ariz., Apr. 21, 1921.]

SYNOPSIS.

In 1913 an investigation was begun to determine within what limits the foothill sections of the Salt River Valley in the vicinity of Phoenix were adapted to citrus culture. Later the scope of the investigation was broadened to include a study of winter temperatures over the whole valley. Upon the basis of records kept at more than 40 stations in the area considered a temperature map was drawn showing the mean minimum temperatures for December and January; the average length of the growing season in the different sections of the valley was determined; a basis was established for forecasting minimum temperatures in the various sections as related to the temperatures expected at the Weather Bureau station in Phoenix; in short, data on winter minimum temperature conditions throughout the valley were gathered and put into such shape as to be useful not only to the citrus grower but to all ranchers, to all intending land buyers, to men looking for the best location for any particular crop and, as it developed, to health seekers searching for the best vantage ground from which to make their fight against tuberculosis. Work during the winter of 1919-20 was directed almost exclusively to the study of temperature inversion as found over the valley, a cross section from the hills on the north down across the Salt River and up into the hills on the south affording an excellent opportunity for such a study.

With the completion of the Roosevelt Dam and distributing system in the Salt River Valley early in 1911, an era of rapid development of the section about Phoenix began. Oranges and grape fruit had been successful in a small way and greatly increased acreage was planted; the growing of sugar beets and sugar cane was undertaken on a large scale; experiments were made in growing figs, grapes, olives, dates, cotton, and many other products. The winters of 1911-12 and 1912-13 were unusually severe. Many of the experiments had been made blindly and were failures. Not all of the failures were due to the severe winters, but killing frosts also had been a contributing cause in many cases. Men were learning to use the soil and water to advantage. Need was felt for a more definite knowledge of winter temperature conditions and it was to supply this need that the survey was undertaken.

The work was started in the fall of 1913 by the late Robert R. Briggs, "to determine the area and limits within which the highest money-value crops could be grown." Citrus groves in favored locations had come through the preceding severe winters with little damage. The fruit ripened early, several weeks ahead of the California product, and brought top prices. The first aim of the survey was to determine what areas were suited to the growing of this highly profitable crop. During the winter of 1913-14 four minimum thermometers were lent to orchardists and exposed in improvised shelters; and one privately equipped station was maintained. Two regular stations had been established also, one in the lowest part of the valley on the river, and the other at Marinette, near the western limit of the area, being studied, where several hundred acres had been planted to sugar cane. Results obtained from these stations showed the need of much more thorough covering of the valley with observing stations.

A much more ambitious program was carried out during the winter of 1914-15. Standard equipment was installed at the four stations already located and seven new stations were established. Twelve thermographs aided very materially in securing good records providing a check against all recorded thermometer readings and bridging over periods where thermometer readings were not taken. Results of this season's work are contained in an unusually elaborate report prepared by the late Robert R. Briggs in July, 1915. No attempt was made to draw conclusions at this early stage of the survey, but the report formed a groundwork for future deductions and suggested lines of development for the investigation.

A visit from the Chief of the Weather Bureau in the spring of 1915 and his interest in the survey gave new impetus to the work. The winter of 1915-16 began very promisingly. Arrangements were made for a much closer supervision of the work, with frequent visits to all stations. Three outfits were shifted to locations where better observational work was promised. The death of Mr. Briggs in January was a severe blow to the survey, as his unfailing interest and enthusiasm had met and overcome many obstacles. The work was continued to the end of the season under the direction of the late Kenneth Meaker, and results were decidedly the best to date in both completeness and accuracy.

Throughout the winters of 1916-17 and 1917-18 the work was carried on under the direction of Meteorologist Robert Q. Grant with but little change aside from the necessary shifting of some stations to secure better cooperation in the keeping of records. The problem of visiting the widely scattered stations frequently enough to keep all the work well in hand was not satisfactorily solved, but much of the work was well done and the mass of reliable data on temperature conditions grew steadily. At the end of the 1917-18 season it was felt that sufficient material had been gathered to map the various sections of the valley.

In the fall of 1917, following a visit to the valley and a study of the results obtained from the survey, Meteorologist William G. Reed recommended that a supplementary series of observations be made to give a temperature cross-section of the valley from north to south. In accordance with these recommendations, the location of stations to give the cross-section was arranged during the summer of 1918. The death of Observer Kenneth Meaker in November left the office too short-handed to undertake the work of moving and setting up the necessary stations and visiting them each week until early

in February. Six new stations were established and used in connection with four old stations to form an approximate north and south line fourteen miles long reaching from the Phoenix Mountains, Squaw Peak, on the north down across the river and up into the Salt River Mountains on the south. Records were kept going until April and while no severe temperatures occurred excellent radiation conditions prevailed much of the time and a good foundation was laid for the next season's work.

In many respects the records of 1919-20 were the most satisfactory of the entire survey. Thermographs had been carefully adjusted and almost without exception gave excellent results. The station most difficult to visit was shifted slightly to a location where an observer was available; and one new station was established in a newly opened section which promised to offer very good prospects for citrus fruits. An arrangement was made with the Southwest Cotton Company for free-air temperatures to be taken by airplane at various elevations over the cross-section during cold, early mornings. Unfortunately, the plane was wrecked before this work could be started. These data, if available, would offer a most interesting comparison with hillside temperatures at the same elevation at the same time. The winter's work began November 1 and continued through the first week of April. Weekly visits were made to eight stations during this period and occasional visits to other stations as opportunity offered. The records obtained are especially interesting as bearing on the study of temperature inversion and air drainage, and, with certain illustrative tracings and graphs, are taken up in the latter part of this report.

In all, 42 stations were considered in making up the report of the survey, 13 of them regular stations, of which 2 are outside the valley proper, and 29 special stations. Credit is due to many cooperative observers in making the report so complete. The results have been worth while. There has already been a considerable demand for copies of the printed map showing temperature lines and length of growing season over the valley. The value to health seekers alone would justify the last season's work. It is felt that in a much larger measure than was at first contemplated the object of the survey, "to determine the area and limits within which the greatest money value crops could be grown," has been attained.

Notes on temperature map.—In making up this temperature map of the Salt River Valley (see chart) mean minimum temperatures for December and January were used, particularly because they were the coldest months of the year, but also because for these months more complete figures were available than for November and February. While for many of the more than 40 stations considered the records were too short to give a fair mean of themselves a number of long records were available, 25 years at Phoenix Weather Bureau Station, 24 at Granite Reef Dam, 20 at Mesa and the University Experiment Farm (Phoenix No. 1), and 16 at Tempe. For these long records minimum-temperature normals were worked out for December and January and departures from the normal figured for each month. These departures were applied as corrections to temperatures at short-record stations for the appropriate months, zones being established over which corrections from the different long records should be applied.

Relation of the mean minimum temperature to the absolute minimum.—It must be admitted that the map fails to touch directly on the very vital subject of absolute low temperatures, the temperatures which damage and against which the gardener, nurseryman, and orchardist must be on his guard. And yet the relationship between these temperatures and the mean minimum is very close. As shown by the following table, which embodies the results of all records of five years or more, there is a difference between the mean minimum and the mean absolute minimum, by months, which very closely approximates 11° F. The difference is so consistently shown by the nine records considered that it probably may be safely applied to all. A further allowance of 8 degrees will cover all probable departures from this mean of the absolute minimum though during the record-breaking cold period in January, 1913, the departure was from 12 to 14 degrees; 4 to 6 degrees greater than for any other year which the record covers.

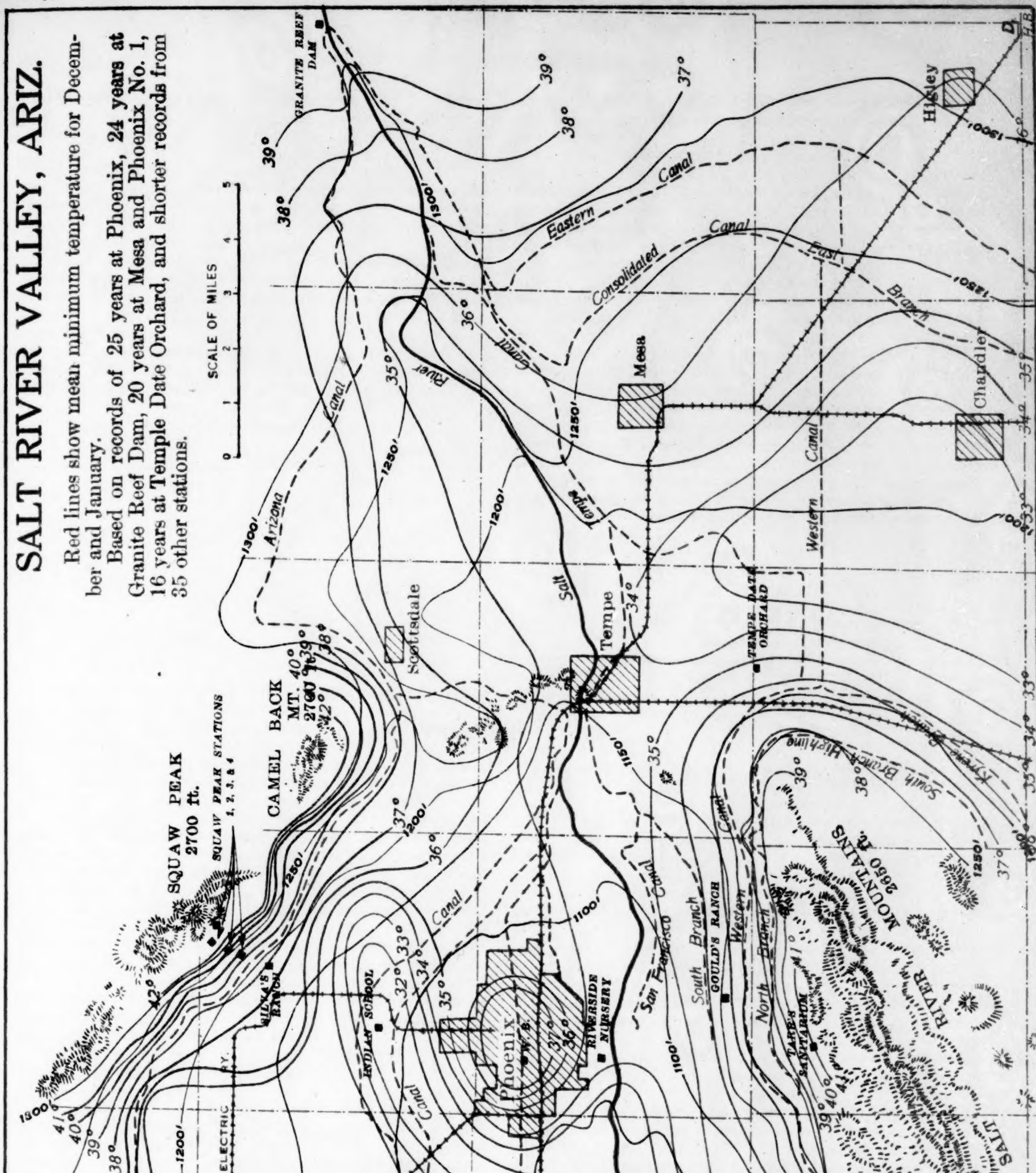
TABLE 1.—*Comparison of mean minimum and absolute minimum temperatures.*

Station.	Length record.	Mean minimum temperature.	Mean absolute minimum temperature.	Difference.	Minimum January, 1913.
	Years.	° F.	° F.	° F.	° F.
Granite Reef Dam	21	40.0	28.8	−11.2	13
Phoenix Weather Bureau	25	38.5	28.0	−10.5	16
Phoenix No. 2	6	37.5	26.6	−10.9	14
Gould's Ranch	5	37.0	25.8	−11.2	(1)
Mesa	18	36.0	25.4	−10.6	(1)
Higley	5	36.0	24.8	−11.2	(1)
Tempe	15	35.0	24.4	−10.6	12
Phœnix No. 1	18	34.5	23.4	−11.1	11
Chandler	6	33.0	23.1	− 9.9	9
Average difference				−10.8	

[1] Record for January, 1913, missing.

Forecasting minimum temperatures.—In issuing frost warnings the value of the forecast is greatly increased by giving the minimum to be expected in each locality. It has been found possible to forecast minima for Phoenix very closely. In the case of extreme or dangerous temperatures the average difference in minima to be expected at Phoenix and any other station in the valley will closely approximate the difference shown by the lines on the map. This is true as an average. In practice, each forecast must be made with a remembrance of the several possible modifying elements. On nights with considerable wind, the difference will be decreased or even reversed occasionally; that is, if the wind persists throughout the night. A calm of three or four hours, even from 4 a. m. on, is sufficient to establish approximately the differences shown on the map. On still, exceptionally good radiation nights the difference will be increased as much as 50 or 60 per cent. In the case of cold waves sweeping down from the north it is not unusual for stations in the southern sections of the valley to be 24 hours later than the northern stations to feel the cold.

Value of the 6 p. m. dew-point in forecasting minimum temperatures.—The 6 p. m. dew-point shown at the Phoenix Station of the Weather Bureau, while of value in forecasting minima likely to occur in Phoenix the following morning, seems to have little value in forecasting minima to be expected in the colder sections of the valley. During the months of November, December, January, and February, 1919-20 season, following clear, good radiation nights, minima at the Indian School, 3 miles north of Phoenix, *averaged* 6 degrees lower than the mean 6 p. m. dew-point of the preceding evenings



SALT RIVER VALLEY, ARIZ.

Red lines show mean minimum temperature for December and January.

Based on records of 25 years at Phoenix, 24 years at Granite Reef Dam, 20 years at Mesa and Phoenix No. 1, 16 years at Temple Date Orchard, and shorter records from 35 other stations.

in Phoenix. In one case the minimum was 14° lower than the dew-point of the preceding evening. Through these months the morning dew-point is normally lower than that at 6 p. m. preceding, but even this will not bring the 6 a. m. dew-point at Phoenix down to the minimum at the Indian school. In extreme cases, the minimum was 7° lower than the 6 a. m. dew-point at Phoenix, while the average difference for the four months was minus three degrees.

Length of the growing season.—For stations with a length of record of five years or more the length of the growing season has been worked out in its relation to the 38.5°, or Phoenix, temperature line as a base. It is realized that the five-year records are too short to be conclusive, but in the absence of longer records several have been used to fill out the scale. The average length of the growing season in Phoenix is 288 days.

TABLE 2.—*Length of the growing season.*

Station.	Length record.	Mean min. temperature.	Season as compared with Phoenix.
	Years.	*°F.*	*Days.*
Granite Reef Dam	16	40.0	+5.0
Phoenix Weather Bureau	25	38.5	0.0
Phoenix No. 2	5	37.5	−1.2
Gould's Ranch	5	37.0	−2.8
Mesa	11	36.0	−17.5
Higley	5	36.0	−18.5
Tempe	14	35.0	−19.0
Phoenix No. 1	11	34.5	−22.0
Chandler	5	33.0	−31.0

There is no question that some of the hillside exposures will give a growing season fully a month longer than Phoenix, but data are not available on which to base exact figures.

The citrus belt and frost protection.—A primary object of the survey was to determine what sections were suitable for citrus culture. The scope of the survey broadened considerably, but sight was not lost of the original idea. While citrus trees grow and there are a few small groves as low as the 34° line, on the map the citrus section of the valley lies above the 35° line and the most desirable sections above the 36° line. The fact that the fruit is nearly always off the trees before the first frost and that the trees are in a semidormant condition through the winter season makes the danger of loss from low temperature, once the trees have made a good start, less than for citrus sections of California. Smudging and flooding as a protection agianst frost are confined almost exclusively to young groves and nurseries. In exceptional cases, where frost is expected and the fruit has not been gathered, picking is rushed all day and far into the night as damage to the fruit rather than to the trees is the danger.

For health seekers.—Health seekers and elderly people who come to the Salt River Valley for the winter have two faults to find with the climate. One is the great diurnal range in temperature and the other is the comparatively high humidity which accompanies the chill of early morning. The climate of the hillsides overlooking the valley is free from these faults. The temperature range will average from six to ten degrees less than on the floor of the valley and this decrease in range comes mostly at the cold end of the day. The chill of the early morning is missing and with it the objectionable high humidity. Few places in the world can offer a more nearly ideal winter climate than these hillsides with the abundant, healing sunshine and warm days of the desert, but without its great temperature range and chill mornings.

Inversion of temperature and air drainage.—The position of the temperature lines on the map in their relation to the contours of elevation establishes the fact of temperature inversion over the Salt River Valley. But the lines also establish the fact that this condition of inversion is not without complications. The area of low temperature lying midway down the slope from the northern hills to the river is the most self-evident inconsistency while the relatively high temperature shown at Phoenix and Riverside Nursery, farther down the slope, call for explanation.

To permit a more detailed study of this inversion layer nine stations were established in the spring of 1919 crossing the valley from north to south. Starting in the north ot Squaw Peak No. 4, 1,750 feet elevation, the line dips down to Riverside Nursery at 1,075 feet, on the north bank of the Salt River, and rises again to 1,400 feet at Tarr's Sanitarium. The total length of the line is 14 miles. The accompanying graphs and thermograph tracings summarize and illustrate the result of a study of the records of temperatures along this cross-section for the season 1919–20.

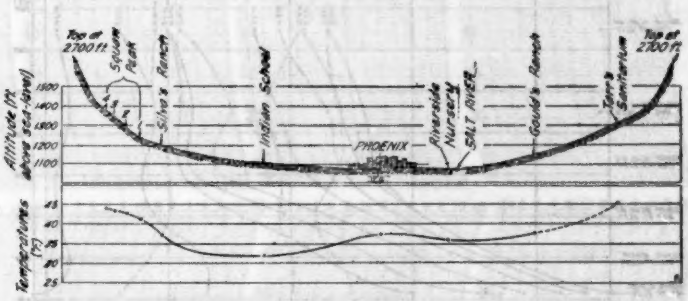


FIG. 1.—A cross-section of the Salt River Valley, Ariz. The upper graph shows a topographic cross-section, and the lower the mean minimum temperatures for December and January along the same section.

The graph showing temperature cross-section of the valley is based on mean minimum temperatures for December and January shown at the stations with correction, given by the long Phoenix record, necessary to reduce them to a true mean. Along this particular line it is apparent that a considerable mass of air at the lower levels fails to show the condition of inversion. The lowest temperature is shown at the Indian School, which is 25 feet higher than Phoenix and 40 feet higher than Riverside Nursery. The map offers an explanation for this seeming inconsistency. It will be observed that the canals north of Phoenix show a wide curve convex toward the mountains. The depression or secondary valley so indicated crosses the slope of the valley proper diagonally from northeast to southwest. It is so slight a depression as to escape entirely the notice of one passing over the ground, with a depth of only about 25 feet and a width of more than 4 miles, but it offers a channel for the cold air streams draining down from the slopes to the north and east. This area with a mean minimum temperature of 32° or lower, shown on the map, is in this flat valley and gets the full benefit of this cold air stream. Land on the south is warmer because of this diversion of the cold air to the southwest, even though of lower elevation than the floor of the subvalley. The relatively high temperatures shown by the Phoenix station of the Weather Bureau, while probably due in considerable measure to the city influence almost certainly are higher because protected from cold air draining down from the north.

Riverside Nursery is protected on the north both by the diversion of the cold air stream and by the city of Phoenix itself with its warming influence. Protection on the south is afforded by the broad bed of the Salt River, which diverts cold air draining from hills on the south to the west. Riverside Nursery is three or four degrees warmer than might be expected if elevation, in relation to the other stations considered, were the determining factor.

The inversion layer appears to have its base some 40 feet above the lowest elevation shown in the section, at least on the north side of the valley. In a general way, this layer may be thought of as made up of superimposed, approximately horizontal air strata in which the temperature rises with the increase in elevation. The positions of the strata within the layer are subject to constant change from the moment the condition of inversion begins, usually late in the afternoon, until the condition is ended by the rising temperatures of the following morning. We are more particularly interested in conditions within the layer at the time of minimum temperature as that is the time at which almost invariably

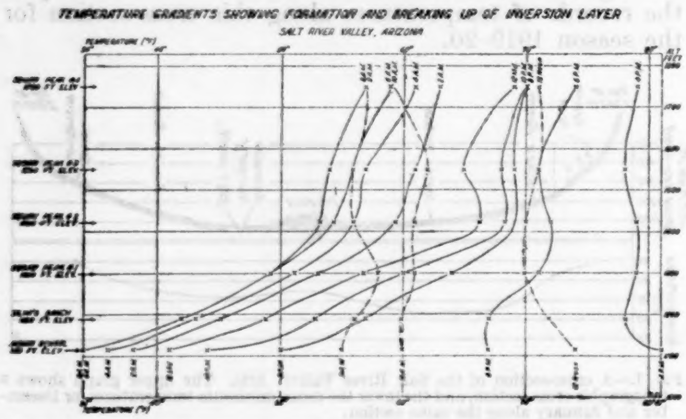


FIG. 2.—The daily variations of the vertical temperature gradient in the Salt River Valley, showing the formation and breaking-up of the inversion layer.

the difference in temperature of the upper and lower strata will be greatest. Mean temperatures at the same elevations on the north and south sides of the valley agree pretty closely at this time, though for individual nights the difference will often be considerable. A south wind will check drainage on the north side of the valley and accelerate it on the south side, or a cross-wind will break up drainage lines on one slope while the other may be calm. Even where a single slope is considered there is a constant variation in the inversion layer from night to night. The section of the layer in which the rate of vertical change is greatest shifts up and down, the depth of the layer almost certainly changes. No two nights show identical records.

It is in relation to study of inversion on a single slope comparatively free from complicating topographic features that most of the graphs and thermograph tracings were made up. The Indian School, being at the foot of the slope drained, is taken as a base and five other stations on an unbroken slope rising 635 feet above it offer excellent opportunity for a study of temperatures within the layer. The thermograph tracings show the development of the inversion condition, as does one set of graphs, from the time of maximum temperature on the preceding day to the time of minimum and the rise of temperature the following morning. Other graphs show simply the temperature gradient within the layer at the time of minimum temperature and represent the mean of a number of days.

Relative humidity appears to be a factor in determining the contrasts of temperature within the inversion layer. Where a number of consecutive mornings are considered, that one with the highest humidity the preceding evening almost invariably shows the smallest contrasts of temperature in the inversion layer. The graphs show the decrease in temperature contrasts through November, December, January, and February, while in March there was a sharp increase. Records show that the mean 6 p. m. relative humidity increased from November through February and dropped sharply in March. It is also suggested that the cooling of the earth itself, the gradual loss of accumulated heat with the advance of winter, may partly explain the progressive decreases in temperature contrast shown by the gradients of December, January, and February, and the increase with the higher day temperatures of March. In other words, there is less heat radiated from the earth itself to influence the temperature of the upper strata of the inversion layer.

DAILY TEMPERATURE VARIATIONS AT THE SURFACE OF THE GROUND IN HOT ARID CLIMATES.

By PAUL RANGE.

[Abstracted from *Meteorologische Zeitschrift*, Mar.–Apr., 1920, pp. 102-104.]

It is of value in studying the effects of erosion to observe the variations of temperature of the upper layers of the ground, because it is certain that such variations play considerable part in the disintegration of the rocks, especially where they are composed of minerals having different coefficients of expansion. Such observations were made for two and one-half years at Kuibis, in German Southwest Africa. Kuibis is 1308 meters above sea level, and lies 175 km. inland from the Atlantic Ocean. Observations were made with a mercurial thermometer possessing a black bulb in an evacuated chamber; an Arago-Davy Actinometer, which is a similarly constructed instrument with an unblackened bulb; a mercurial maximum thermometer and an alcohol minimum thermometer. Observations were made in the air and on the surface of the ground.

The black-bulb thermometer readings averaged 8° C. higher on the ground then in the air for the year, probably owing to the nature of the soil. The following table shows the air and ground temperatures for the year:

	Minimum.	Maximum.	Mean.	Range.
	°C.	°C.	°C.	°C.
Air	18.3	30.8	24.5	12.5
Ground	14.9	47.8	31.2	32.9
Difference	−3.4	17.0	6.7	20.4

When compared with the table given by Hann[1] for the Indian station, Jaipur, it is found that the extremes at Kuibis are greater than those of the Indian station, partly because of its greater elevation and partly because of the great amount of sunshine. The minimum occurs about sunrise—in winter about 7 a. m. and in summer about 5 a. m. The maximum occurs about noon. The range of temperature between sunrise and noon in summer is about 60° C. and in winter is about 50° C. These

[1] *Meteorologie*, p. 48.

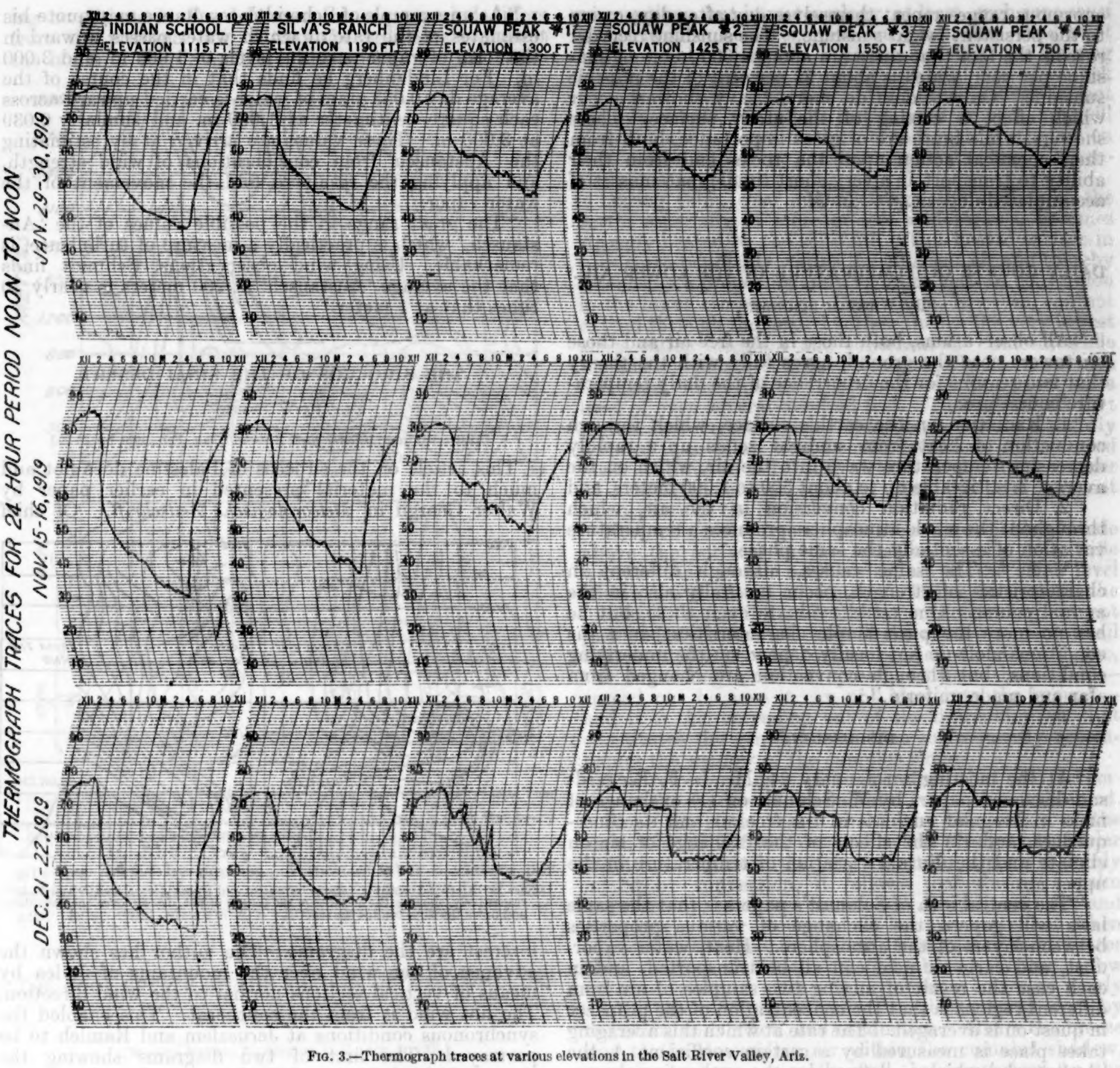


FIG. 3.—Thermograph traces at various elevations in the Salt River Valley, Ariz.

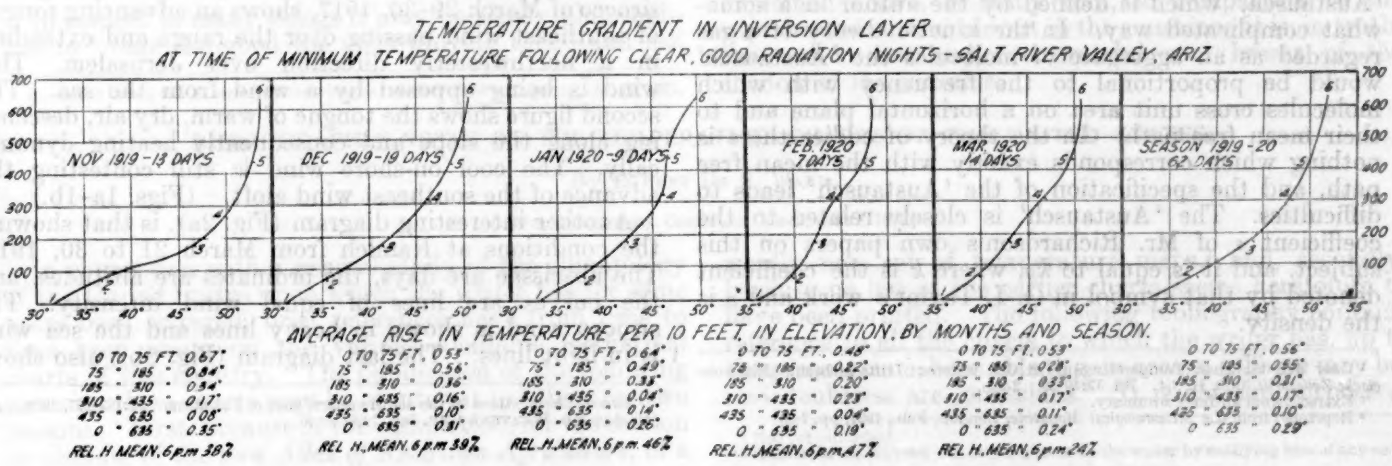


FIG. 4.—Mean temperature gradients within the inversion layer at the time of minimum temperature in the Salt River Valley.

enormous ranges repeat themselves day after day, owing to the persistent bright sunshine. The sunshine recorder reveals the fact that there are about 4,000 hours of sunshine per year, which is about 92 per cent of the possible sunshine. Only seldom do short, heavy showers occur which effect a cooling of the stony surface. These showers, while brief, are of great importance, both from their chemical action upon the rocks and from their ability to transport, in a very short time, great masses of accumulated deposit.—*C. L. M.*

DAILY COURSE OF TEMPERATURE IN THE LOWER AIR.[1]

By WILHELM SCHMIDT.

"All observations, both those in the free air and those on towers near the ground, agree fully with the theory that two reasons for the occurrence of the daily temperature course are:

"1. Radiation on the earth's surface, which through conduction of heat from sunlight sends up a rapidly decreasing temperature wave into the air, which on the average is noticeable up to about 500 to 1,000 meters, and

"2. Direct radiation conversion in the air, which throughout the whole atmosphere produces a temperature variation of essentially the same phase.

"* * * The same causes, although different in characteristics of strength, occur naturally also in the annual course. One could evaluate even these, but he has no more the pure simple characteristics, since the conditions aloft do not locally depend on the underlying conditions, but through convection are changed from afar and made uniform." [2]

DISCUSSION.[3]

"At the meeting, on January 24, Mr. L. F. Richardson discussed papers by W. Schmidt on (1) exchange of mass in irregular currents in the free air and its consequences, and (2) the effects of the exchange of air on climate and the diurnal variation of temperature in the upper air.

"The central idea of Schmidt's papers is that the same laws will govern the exchange of various properties between layers of the atmosphere. Heat, water vapor, dust, and carbonic acid can all be transported, and in each case the result of mixing two samples of air from different regions is that the concentration of the property in question is averaged. The rate at which this averaging takes place is measured by a certain coefficient A, the 'Austausch,' which is defined by the author in a somewhat complicated way. In the kinetic theory of a gas regarded as an aggregate of molecules the 'Austausch' would be proportional to the frequency with which molecules cross unit area on a horizontal plane and to their mean free path. In the theory of eddies there is nothing which corresponds exactly with the mean free path, and the specification of the 'Austausch' leads to difficulties. The 'Austausch' is closely related to the coefficient ϵ of Mr. Richardson's own papers on this subject, and it is equal to $k\rho$, where k is the coefficient denoted by that symbol in G. I. Taylor's work and ρ is the density.

"As an example of Schmidt's results we may quote his estimates of the rate at which water passes upward in the form of vapor past the levels of 1,000 m. and 3,000 m. For Lindenberg he finds that in the course of the average day 0.063 gram of water is carried upward across each square centimeter at 1,000 m. and similarly 0.039 at 3,000 m. These values are arrived at by estimating the 'Austausch' from considerations of wind strength, and applying the result to find the movement of the water vapor.

"The great range in the possible values of the 'Austausch,' which is practically a measure of turbulence, is remarkable. Using wind observations, Schmidt finds that the average 'Austausch' at 200 meters is nearly 30 times that at 1 meter."

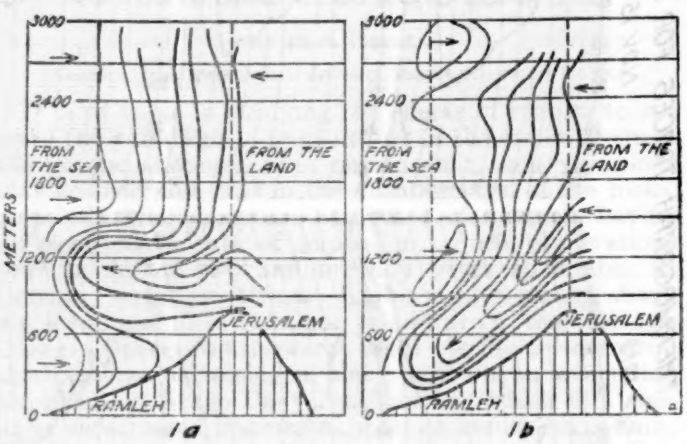
[1] Über den täglichen Temperaturgang in den unteren Luftschichten. *Meteorologische Zeitschrift*, 1920, H. 3/4. Bd. 37:49-59. 2 figs.
[2] Extracts from author's summary.
[3] Reprinted from the *Meteorological Magazine*, London, Feb., 1921, pp. 7-8.

THE SIROCCOS OF THE SINAI DESERT.

By W. SPÄTH.

[Abstracted from *Meteorologische Zeitschrift*, Jan.-Feb., 1920, pp. 26-29.]

This article on the siroccos of Palestine does not add much to the material presented in earlier paper by Walter Georgii in *Meteorologische Zeitschrift*.[1] Of chief



FIGS. 1a-1b.—Wind conditions above Jerusalem and Ramleh, on March 29 and 30, 1917, respectively, showing the advance of the tongue of hot, dry air over the mountains and down the slope toward the sea.

interest are the diagrams. The author has shown the advance of the wind over the mountains of Judea by means of vertical sections normal to the wind direction. The hot wind is from the southeast. This enabled the synchronous conditions at Jerusalem and Ramleh to be portrayed. The first of two diagrams showing the sirocco of March 29–30, 1917, shows an advancing tongue of southeast wind passing over the range and extending in a northwesterly direction over Jerusalem. This wind is being opposed by a wind from the sea. The second figure shows the tongue of warm, dry air, descending along the slope and consequently heating dynamically. The cool on-shore wind is still contesting the advance of the southeast wind aloft. (Figs. 1a–1b.)

Another interesting diagram (Fig. 2a), is that showing the conditions at Ramleh from March 21 to 30, 1917. The abscissae are days, the ordinates are altitudes, and the curves are lines of equal wind intensity. The sirocco wind is shown in heavy lines and the sea wind is in light lines. The last diagram (Fig. 2b), also show-

[1] Sirocco observations in the southwestern part of Palestine. 36:193-197, 1919. Abstract in MO. WEATHER REV. Jan. 1920, p. 40.

ing conditions at Ramleh over the same period differs from the previous one in that the ordinates represent the hours of the day. Here, also winds of equal intensity are joined by curves.

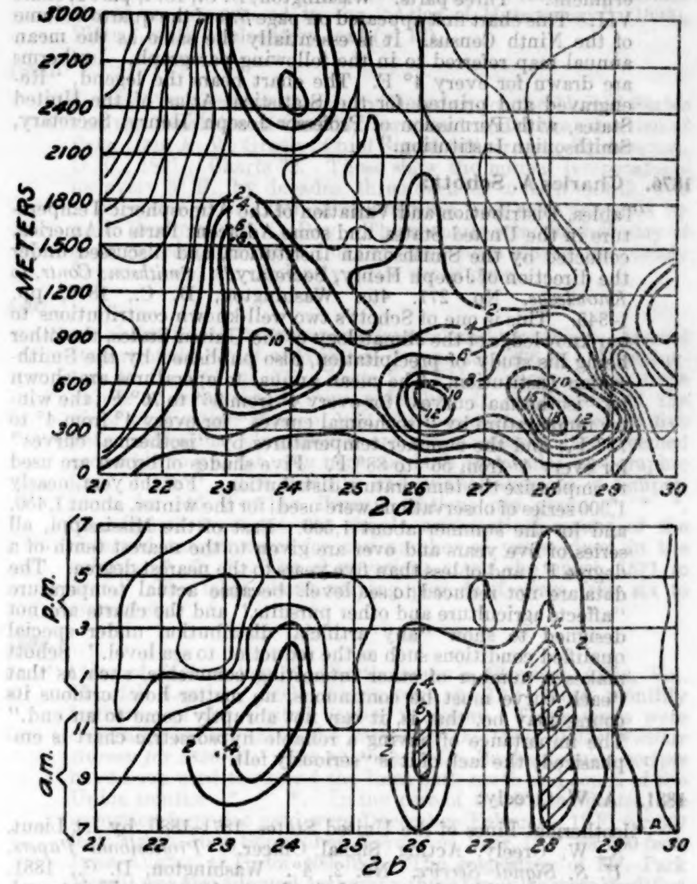


FIG. 2a.—Lines of equal wind strength above Ramleh, March 21-30, 1917; heavy lines being sirocco wind, light lines, sea wind.
FIG. 2b.—Lines of equal surface wind strength at Ramleh, March 21-30, 1917; heavy lines being sirocco wind, light lines, sea wind.

Winds of over 6 meters per second are sufficient to carry with them clouds of dust and these dust storms are shown by hachure.—*C. L. M.*

THE COOL BREEZE OF THE SHADOW OF THE CUMULUS.[1]

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., Apr. 21, 1921.]

In respect to many things it may be sanely philosophical to "take the good the gods provide thee" and ask no questions, but in meteorology, at least, such *sans souci* is unscientific, however great our gratitude. And so it happens that when, on a sweltering day, the passing cumulus, for instance, brings its grateful breeze we ask whence it came and how. Well, the answer is not entirely simple, not all in just a word or two, but still clear enough to give something of that mental satisfaction that comes with every conscious understanding. Essentially it is as follows:

During calm, clear summer days, the surface of the earth, especially in more or less arid regions, becomes strongly heated by the sunshine. This heated surface in turn correspondingly warms the adjacent air and thereby establishes a proportionately vigorous vertical convection in the lower atmosphere. Convection, however, can not extend through the heated surface, hence the very lowest air is rather stagnant and superheated. Indeed, while the amount of convectional mixing rapidly increases with elevation, nevertheless it often is still imperfect at a level of even several hundred feet. Throughout all that region, however, in which convection is perfect a slightly warmed mass of air would continue to rise, and a cooled mass continue to fall, being at each level a little warmer or a little cooler, respectively, than the then adjacent atmosphere of the same level.

Now, obviously, free air (air at an appreciable altitude above the surface) in the sunshine usually is a trifle warmer than is the neighboring air at the same level within the shade of a cumulus. Hence, in general, the former is ascending and the latter descending, except just under the forward base of the cloud—a mere detail that need not here be further considered. Clearly, too, the descending air must spread out near the surface—spread out because it can not blow into the ground—and it is this spreading out of the descending air that constitutes the gentle breeze that so frequently accompanies the shadow of the cumulus cloud.

The refreshing drop in temperature that also accompanies the shadow of the cumulus is yet to be explained.

Since the air is heated mainly by the surface of the earth which itself was warmed by the absorption of solar radiation, and since the very lowest air is not vigorously mixed by convection, it follows that during a calm summer day, sand and barren soil, the adjacent air, and even one's outer clothing, all become quite hot when exposed to the sunshine—often 10 degrees or more hotter than the free air 50 to 100 feet above. Within a few minutes, however, after a heavy shadow comes on nearly all this excess of temperature has disappeared—lost by radiation, convection, and conduction. Hence the breeze due to the descending air within the cumulus shadow, explained above, is really cool, in comparison to the superheated surface air out in the sunshine; it is, in truth, the well-known and ever-grateful cool breeze of the shadow of the cumulus.

[1] Presented before the American Meteorological Society at Washington, Apr. 21, 1921.

BIBLIOGRAPHIC NOTES ON THE TEMPERATURE CHARTS OF THE UNITED STATES.

By ROBERT DE C. WARD.

[Harvard University, Cambridge, Mass., June 8, 1921.]

In connection with a general study of the climatology of the United States upon which the writer has for some years been engaged, brief references have from time to time been made on the various available isothermal charts of this country. The publication of the following notes on these charts may be of interest to others for two reasons. First, because of the completion, for the section on climate of the new *Atlas of American Agriculture*, of a wholly new set of temperature maps,[1] and, secondly, because no list of the earlier charts seems heretofore to have been printed. The following bibliography contains reference to all the charts to which the writer has, up to the present time, been able to gain access. There may be, and doubtless are, omissions.[2] It is not the purpose of

[1] Not yet published.
[2] Readers of the REVIEW will confer a favor on the writer by notifying him of any such.

the present note to include reference to the numerous isothermal charts for individual States or districts, which have from time to time appeared in various scattered publications,[3] nor to isothermal maps for individual months which have for many years been regularly included in the successive issues of the MONTHLY WEATHER REVIEW.

For convenience, and in order to make the present bibliographic note somewhat more useful to students generally, brief reference is made (B) to a few miscellaneous temperature charts of the United States, and (C) to the standard world temperature charts which are necessary in making any comparative study of the temperature conditions of the United States in relation to those of other parts of the world.

A. MEAN ANNUAL, SEASONAL, AND MONTHLY ISOTHERMAL CHARTS OF THE UNITED STATES.

1844. Samuel Forry.

"Researches in Elucidation of the Distribution of Heat over the Globe, and specially of the Climatic Features peculiar to the Region of the United States." *Amer. Jour. Sci.*, 1844, Vol. **47**, pp. 18–50, 221–241; pls. 2. Pl. I illustrates "the general laws of temperature throughout the United States" by means of five lines of equal temperature, one ("isothermal") for the year; two ("isocheimal") for winter and two ("isotheral") for summer.

1855. Lorin Blodget.

"Distribution of Temperature and Explanation of the Isothermal Charts." *Army Met. Register, for Twelve Years, from 1843 to 1854, inclusive.*" Washington, D. C., 1855, pp. 688–733. Annual and four seasonal charts, "designed and prepared by Lorin Blodget under the direction of Bvt. Brig. Gen. Thomas Lawson, Surgeon General, U. S. A." Isotherms (in red) are drawn heavy for every 5°; light for intervals of less than 5°, and in broken lines where "doubtful." The "minimum or lowest position" and the "maximum or most northern position" of certain isotherms are also shown. Blodget's "isothermal illustrations" were "first presented to the American Association for the Advancement of Science in 1853," but the charts were not published in the proceedings of the association.

1857. Lorin Blodget.

"Climatology of the United States . . . . with Isothermal and Rain Charts for each Season, the Extreme Months, and the Year . . . ," etc. Large 8vo. Philadelphia, 1857. Pp. 257–316 concern "distribution of heat in the United States, monthly and for the seasons, with explanation of the isothermal charts," of which there are five. These are essentially the same as those originally included in the *Army Meteorological Register*, above referred to. The "number of series of observations consulted" for the United States was 583 (p. 33). The mean temperatures (given in the tables) were "principally obtained from the simple arithmetical mean of the several daily observations, and without correction by any scale derived from the daily curve of temperature" (p. 36). The observations were made at various hours, thrice daily, twice daily, and some means were obtained from the daily extremes. The charts are obviously very incomplete and inaccurate in the light of present-day knowledge. Some isotherms divide; many are only partly drawn, and remain "hanging." In view of the date of publication, however, Blodget's charts and his discussion are remarkably complete. Another chart (opposite p. 210), for purposes of "comparison of temperatures for the temperate latitudes of the northern hemisphere," shows the January, July and mean annual isotherms between latitudes 20° and 80° N.

1874. Charles A. Schott.

"Temperature Chart of the United States. Showing the Distribution, by Isothermal Lines, of the Mean Temperature for the Year. Constructed under the direction of Professor Joseph Henry, Secretary, Smithsonian Institute, by Charles A. Schott, assistant, U. S. Coast Survey, in October, 1872." In Francis A. Walker: "Statistical Atlas of the United States, based on the Results of the Ninth Census, with Contributions from many Eminent Men of Science and Several Departments of the Government." Three parts. Washington, D. C., 1874, part I, chart VII. This chart first appeared on page 579 of the quarto volume of the Ninth Census. It is essentially the same as the mean annual map referred to in the following paragraph. Isotherms are drawn for every 4° F. The chart bears the legend, "Re-engraved and printed for the Statistical Atlas of the United States, with Permission of Professor Joseph Henry, Secretary, Smithsonian Institution."

1876. Charles A. Schott:

"Tables, Distribution and Variation of the Atmospheric Temperature in the United States, and some Adjacent Parts of America, collected by the Smithsonian Institution, and discussed under the direction of Joseph Henry, Secretary." *Smithson. Contr. to Knowledge.* No. 277. 4to. Washington, D. C., 1876, pp. 1–345. This is one of Schott's two well-known contributions to our knowledge of the climatology of the United States, the other being his study of precipitation, also published by the Smithsonian Institution. The mean annual temperatures are shown by "isothermal curves" for every 4° from 36° to 76° F.; the winter temperature by "isocheimal curves" for every 4° from 4° to 72° F.; and the summer temperatures by "isothermal curves" for every 4° from 56° to 88° F. Five shades of brown are used to emphasize the temperature distribution. For the year, nearly 1,300 series of observations were used; for the winter, about 1,450, and for the summer about 1,500. East of the Mississippi, all series of five years and over are given to the nearest tenth of a degree F., and of less than five years to the nearest degree. The data are not reduced to sea level, because actual temperature "affects agriculture and other pursuits," and the charts are not designed to show "any artificial distribution under special qualified conditions such as the reduction to sea level." Schott makes a number of other interesting comments, such as that "each curve must be continuous, no matter how tortuous its course may be, that is, it can not abruptly come to an end." The importance of having a reliable hypsometric chart is emphasized; the lack of it is "seriously felt."

1881. A. W. Greely:

"Isothermal Lines of the United States, 1871–1880, by 1st Lieut. A. W. Greely, Acting Signal Officer." *Professional Papers, U. S. Signal Service.* No. 2, 4°. Washington, D. C., 1881. Twelve monthly charts, with isotherms for every 5° interval. "No similar charts have been recently published" (Preface). "No means have been used which do not cover at least three consecutive years, and but very few of less than six years duration. * * * It was deemed best not to correct for want of uniformity in methods of deducing daily means. * * * The isotherms where crossing mountain ranges express the temperature, not of the peaks, or elevated or isolated stations, but of adjacent valleys. * * * The method has been adopted of connecting mean temperatures of equal value in contiguous valleys or plateaus by a nearly direct route, giving the lines only such curves and direction as has been suggested by the data collected. * * * Even were it desirable to draw lines based on elevations and the very scanty data available from elevated stations, the size of these charts would have precluded it." The observations used were all thrice daily, but taken at various hours. No general discussion accompanied this set of charts. The January and July charts have been several times reproduced, *e. g.*, in *A. W. Greely:* "American Weather," 8°, New York, 1888 (Charts V, VI), and in F. Waldo: "Elementary Meteorology," 4to, New York, 1896, Figs. 95, 96.

1886. William Ferrel:

"Report of Professor William Ferrel, Assistant, on Reduction of Barometric Pressure to Sea Level and Standard Gravity." *Appendix 23, Annual Report of the Chief Signal Officer for 1886.* 4°. Washington, D. C., 1886, pp. 221–237. Three sea-level isothermal charts, for the year, January and July, for use in barometric reductions. The reduction formula used is 1° in 600 feet. "This is only about one-half of the usual rate obtained in various parts of the world * * * but for the reduction of the plateau stations of the western part of the United States this rate is evidently much too great." Isotherms are drawn for every 5° F. (year, 35°–70° F.; January, 0°–60°; July, 65°–85°).

1886. J. Hann:

"Atlas der Meteorologie," *Berghaus' Physikal-Atlas, Abt. III.* Gotha, 1887. This atlas contains three charts of mean annual, January and July isotherms for North America, colored, the lines

[3] As examples of such special charts mention may be made of the following: *Alexander Winchell:* "The Isothermals of the Lake Region," *Proc. Amer. Ass. Adv. Sci.*, Vol. 19, 1870, pp. 106–117 (with detailed isothermal charts for January and July, still of interest), and of the large-scale set of annual and seasonal isothermal charts of Maryland, including Delaware and the District of Columbia ("Climatic Charts of Maryland, including Delaware and the District of Columbia, together with a Map showing the Distribution of the Geological and Soil Formations," 18x33 ins., *Maryland Weather Service*, Baltimore, Md., 1893. 3 pp. 10 ch. 1 map. *Reviewed; Amer. Met. Journ.*, Vol. 10, 1893–94, pp. 489–490).

being drawn for every 2° C., and one chart of the January isotherms for the eastern United States (on a somewhat larger scale), together with the lines of equal annual minimum temperatures. The data used were those available up to 1884, and the reduction formula is 0.5° C. per 100 meters (1° F. for 365 feet). These four charts are reproduced in the "Atlas of Meteorology" (1899), Plate 7, with explanatory text (p. 12).

1891.

"Normal Temperature Charts, by Decades, for the United States and the Dominion of Canada," prepared under the direction of Brig. Gen. A. W. Greely, Chief Signal Officer, fol., Washington, D. C., 1891. Charts 72. These show the normal temperatures for every 5° F., by decades, three decades to each month, at 8 a. m. and 8 p. m., 75th meridian time, and were prepared by A. J. Henry and P. C. Day. These charts were in their day of great interest and value, but have now been almost completely forgotten, and are obviously quite out of date.

1897.

Normal Sea-Level Temperatures (annual and monthly). Annual Report of the Chief of Weather Bureau for 1896-97, Washington, D. C., 1897, p. 279, Charts V-XVII. "Normal or average values of temperature were published in the Report of the Chief of Weather Bureau, 1891-92; inasmuch, however, as five years' additional observations are now available, it is deemed profitable to publish new normals, both in tabular and graphic form * * *. The monthly and annual averages of temperature for 140 Weather Bureau stations are given * * *. The figures represent the simple arithmetical means of the observed temperatures for the number of years given in the column * * *. The observations cover the epoch 1871 to 1895." The table shows varying periods of years, from six to twenty-six.

1899.

"Atlas of Meteorology." (Bartholomew's Physical Atlas, Vol. III, fol. London, 1899. Pl. 8; text, p. 12.) Mean monthly isotherms of the United States, in colors. These maps were originally published in the *Report of the Chief of the Weather Bureau for 1896-97*. (See above.) "Dr. Buchan's manuscripts have been used to extend the lines both north and south of the Union frontier * * *. In the case of the United States, the reduction formulae used were December-February, 1° F. for 667 feet; March-May, September-November, year, 1° F. for 500 feet; June-August, 1° F. for 400 feet. The suggestion of Mr. Park Morrill was also adopted,[4] whereby these formulae were modified by local corrections determined as follows: The normal reduced temperatures were charted for a considerable extent of country and isotherms drawn. These are more or less wavy, and irregular, as a result of local peculiarities of temperature. Through these wavy lines smooth lines are drawn with a free hand. The isothermal chart thus formed is believed to closely approximate to the chart of sea-level temperatures.

1906(?).

"Climatic Charts of the United States." U. S. Weather Bureau. Washington, D. C. 10 x 16 ins. Unbound. There are three charts showing the "normal temperature of the air at the surface of the earth" for the year, January and July. These charts were first issued about 1906 and have been reprinted several times, but there has been no new edition. The legend on one set of these charts in the writer's collection says: "Compiled from observation at the regular Weather Bureau and selected cooperative stations between 1871 and 1908." On another set of these charts there is no reference to the period covered by the observations, but the writer is informed by Mr. P. C. Day, of the Weather Bureau, that the basic period is 33 years, from 1873 to 1905, inclusive. Isotherms are drawn for every 5° F. These charts are now the Weather Bureau "standard," and will remain so until the new temperature maps prepared for the *Atlas of American Agriculture* are finally given publication.

1906. Alfred J. Henry:

"Climatology of the United States." Bulletin Q. U. S. Weather Bureau. 4to. Washington, D. C., 1906. Pls. X-XII. Three charts of the normal surface temperatures for the year, January and July, with isotherms for every 5°. The text (pp. 25-26) discusses the mean annual chart only. These charts were based upon the records of the period 1871-1903. In general no record of less than 24 years was used.

[4] Annual Meteorological Summary, 1895, p. 493.

B. MISCELLANEOUS TEMPERATURE CHARTS OF THE UNITED STATES.

The following bibliography includes some of the more important miscellaneous temperature charts which may be useful in a study of the temperature conditions of the United States.

"Highest Temperatures ever Observed at the Regular Weather Bureau and Selected Cooperative Stations (Fahr.)." "Lowest Temperatures ever Observed at the Regular Weather Bureau and Selected Cooperative Stations (Fahr.)." *Climatic Charts, U. S. Weather Bureau.* One set of these two charts, which are the present "standard" for the United States, bears the legend "highest (lowest) temperatures recorded in the shade at the regular Weather Bureau and selected cooperative stations since their establishment to include December 31, 1908, except in case of stations closed prior to that date, covering in extreme cases a period of about 38 years." Another set of the charts bears the legend: "This chart represents the highest (lowest) temperatures ever recorded in the shade at the regular Weather Bureau and selected cooperative stations," without mention of the period covered by the observations.

Bulletin Q (U. S. Weather Bureau, 1906) includes a chart of absolute maximum temperatures (Pl. XIII) and one of absolute minimum temperatures (Pl. XIV). The discussion (pp. 26-29) does not mention the period covered by the observations, but reference is made to Table II (pp. 88-92) as containing "the numerical values for a number of the principal stations," and there is a statement that "in the preparation of the charts a few records were used that do not appear in the table." The table bears the caption "Absolute Maximum and Minimum Temperatures for Selected Stations, with Year of Occurrence, 1871-1903." The number of years of record varies, but is generally between 25 and 33. Another short table (p. 28) gives "Extremes of Temperature in Mountain Districts," the stations including Mount Washington, N. H., Mount Mitchell, N. C., Pikes Peak, Colo., Summit, Calif., and others. The two charts in *Bulletin Q*, therefore, do not cover as long periods as do those which form part of the "Climatic Charts." Hence, the former naturally show somewhat lower maxima over some sections, and somewhat higher minima. An earlier publication on maximum and minimum temperatures was that entitled "Charts Showing Maximum and Minimum Temperatures, by Decades, for All Years," Prepared under the Direction of Brig. Gen. A. W. Greely, Chief Signal Officer fol. Washington, D. C., 1891. Chart 37. The period covered is 1872 to June 30, 1891; the year and date of occurrence are shown in figures; no lines are drawn. One chart (37) shows "the chief maxima and minima temperatures in the United States and the Dominion of Canada from the beginning of the use of self-registering theremometers (generally in 1872 in the United States) to the present time" (1891).

Absolute maximum and absolute minimum temperature charts were also included in Greely's *"American Weather"* (1888), Charts VII and VIII, and bear the legend, "Maximum (Minimum) Temperatures ever observed, 1871-1888." These are also included in Waldo's "Elementary Meteorology" (1896), Figs. 97 and 98 ("after Greely").

Other charts which are readily accessible and are still useful, in bibliographic and historical studies although

rather out of date at the present time, are the following: In Greely's "*American Weather:*" "Continuance of Daily Mean Temperature above 50° F.," Chart IX (Lines are drawn for the periods of months; figures are given for days); "Continuance of Daily Mean Temperature below 32° F.," Chart X; "Variability of Temperature for January," Chart XI (mean diurnal; lines for 1° intervals). In Waldo's "*Elementary Meteorology*": "Absolute Amplitude of Shade Temperatures (after Greely)," Fig. 99; "Variability of Average Daily Temperatures in January in the United States (after Greely)," Fig. 101; "Relative Frequency of Falls of Temperature of over 20° in 24 hours (after Russell)," Fig. 102. In *Bulletin Q:* "Mean Maximum Temperatures for July," Pl. XV; "Mean Minimum Temperatures for January," Pl. XVI; "Absolute Range in Monthly Mean Temperature, January," Pl. XVII; "Absolute Range in Monthly Mean Temperature, July," Pl. XVIII.

The earliest publication of temperature charts of the United States for "popular" use seems to have been that of Dr. Charles Denison, who, in 1884 (Rand, McNally & Co., Chicago), issued a set comprising an annual and four seasonal climatic maps, showing, by lines and by colors, the distribution of temperature, rainfall, cloudiness, and relative humidity, and by arrows, the prevailing winds. The maps and tables were "compiled from data of the Signal Service Bureau," obviously very fragmentary at that early date. Reviewed by W. M. Davis, in *Amer. Met. Journ.*, vol. 1, 1884-85, pp. 545-546. A so-called "popular edition," with additions, was published in 1893 (large 8°, 1893, pp. 47).

C. ANNUAL AND MONTHLY ISOTHERMAL CHARTS OF THE WORLD.

No study of the temperatures of any single country is complete unless it includes a comparison with those of other parts of the world. For this reason the following references to the present standard world temperature charts are here added.

The one uniform and complete series of annual and monthly isothermal charts is the "Challenger" set, originally published in the *Report on Atmospheric Circulation*, "*Challenger*" *Reports, Physics and Chemistry*, Vol. II, Edinburgh, 1889, and all reproduced in the *Atlas of Meteorology*, pls. 1 and 3 (text pp. 7, 9-10). The mean annual, January, and July charts have since been reproduced in a large number of publications. These charts are based on observations taken during the same period of 15 years, 1870-1884, and a uniform reduction formula of 1° F. for 270 ft. (1° C. for 200 meters).[5]

No newer world charts of the mean annual maxima, mean annual minima, and mean annual extreme range than those of Dr. van Bebber, originally published in 1893, are available.[6]

These three charts are reproduced, in colors, in the *Atlas of Meteorology*, pl. 2, text, pp. 8-9, with the statement that "some corrections have been kindly communicated by the author" (i. e. Dr. van Bebber). Charts of this sort are obviously constructed with great difficulty, and it is hardly to be expected that a new series will be prepared in the near future.

[5] Historical, bibliographical, and descriptive notes on various temperature charts will be found in the *Atlas of Meteorology* text, pp. 6-10. Reference may also be made to *E. W. Woolard:* "Historical Note on Charts of the Distribution of Temperature, Pressure, and Winds over the Surface of the Earth," *Month. Weather Rev.*, July, 1920, 48, 408-411.

[6] W. J. van Bebber: "Die Verteilung der Warmeextreme über die Erdoberfläche," *Pet. Mitt.*, vol. 39, 1893.

The "standard" world charts of mean annual ranges and of isanomalous temperatures were constructed by former students of Professor W. M. Davis, of Harvard University, and under his direction. The mean annual range chart, based on the "Challenger" January and July isothermal charts, was the work of J. L. S. Connolly,[7] and is reproduced, in colors, in the *Atlas of Meteorology*, pl. 2, text, p. 8. It also appears in Davis's "*Elementary Meteorology*," fig. 18, and elsewhere. The isanomalous charts were constructed by S. F. Batchelder, and included the mean annual, January and July isonomalies.[8] The January and July charts were the only ones printed, and these are reproduced, in colors, in the *Atlas of Meteorology*, pl. 2, text, p. 8, in Davis's "*Elementary Meteorology*," figs, 16 and 17, and elsewhere. The original chart showing the mean annual isanomalous lines, which has never been published, is in the Climatological Laboratory of Harvard University.

In the study of the larger temperature conditions of the United States, especially in relation to those of the world as a whole, the "thermal regions" of the late Dr. A. J. Herbertson are very useful.[9]

Dr. Herbertson's three essential maps are reproduced, on a large scale, in the series of *Oxford Wall Maps*.[10]

The map of the thermal regions of the world shows 10 different regions, indicated by different colors and divided according to the characteristics of their seasons, the distinguishing temperatures being over 68°; 50°-68°; 32°-50°; and below 32° (F.). These are actual temperatures, not reduced to sea level. The same wall map also shows the mean actual temperatures for January and for July, in colors, the critical actual temperatures being the same as those used in the thermal regions. Areas over 68° are pink; between 50° and 68°, yellow; between 32° and 50°, green; and below 32°, blue. On all three maps the critical *sea-level* isotherms of the "Challenger" charts are shown, for purposes of comparison between sea-level and actual temperatures.

LEVEL OF CONSTANT AIR DENSITY.[1]

By W. J. HUMPHREYS, Professor of Meteorological Physics.

[Weather Bureau, Washington, D. C.]

Sir Napier Shaw says[2] that at the level of 8 kilometers the density of the air "is equal all over the globe at all seasons of the year." Statistical evidence of the truth of this statement occurs in density-elevation tables by W. H. Dines,[3] and by Gregg.[4] I was unable, however, to find any general or theoretical proof of it, and therefore tried to prove it myself; and as this proof is both short and easy it may be worth passing along, even though it must bear the warning label "perhaps not new."

As is well known, both the composition and the sea-level pressure of the atmosphere are roughly constant from season to season and from place to place. Clearly

[7] J. L. S. Connolly: "A New Chart of Equal Annual Ranges of Temperature," *Amer. Met. Journ.*, vol. 10, 1893, 94, pp. 505-506, 1 ch.

[8] S. F. Batchelder: "A New Series of Isanomalous Temperature Charts, based on Buchan's Isothermal Charts," *ibid*, vol. 10, 1893-94, pp. 451-474, chs. 2.

[9] A. J. Herbertson: "The Thermal Regions of the Globe," *Georgr. Journ.*, vol. 40, 1912, pp. 518-532; reprinted in *Mo. Weather Rev.*, vol. 42, 1914, pp. 286-289; reviewed by *R. De C. Ward:* "A Note on the Classification of Climates," *Bull. Amer. Geogr. Soc.*, vol. 46, 1914, pp. 108-116.

[10] Oxford University Press; 60 x 40 inches, mounted on cloth. Three maps on one sheet.

[1] Presented at meeting of American Meteorological Society, Washington, D. C., Apr. 21, 1921.

[2] *Nature*, 1920. 106:436.

[3] *Geophys. Memoirs*, No. 13, p. 63, 1919.

[4] MONTHLY WEATHER REVIEW, Jan., 1920. 48:10.

then, to this approximation, the sea level density of the air varies inversely as the absolute temperature. But an increase of the temperature of the air not only decreases the surface density owing to expansion, but also, as a result of this expansion, increases the pressure at each level above the surface.

Furthermore, the ratio of both seasonal and latitudinal temperature changes to the absolute temperature are roughly constant from the surface up to the stratosphere. Through this height, therefore, a temperature gain tends, on the one hand, to decrease the density of the air by thermal expansion, and, on the other, to increase it by mechanical compression. Clearly, then, that level at which the one tendency exactly balances the other must be a level of constant density.

To determine this level, let v, p, ρ, and T, be the volume, pressure, density, and absolute temperature, respectively, of a quantity of air at the height h above sea level, and H the height of the homogeneous atmosphere *above* h. Then, up to such height, that is, to the top of the troposphere, as $\Delta T/T$ is constant

$$\frac{\text{pressure contraction}}{v} = -\frac{\delta v}{v} = \frac{\delta p}{p} = \frac{h\rho g \Delta T/T}{H\rho g},$$

and

$$\frac{\text{temperature expansion}}{v} = \frac{\Delta v}{v} = \frac{\Delta T}{T}.$$

But, as explained, density is constant where

$$-\frac{\delta v}{v} = \frac{\Delta v}{v},$$

or where

$$\frac{h\rho g \Delta T/T}{H\rho g} = \frac{\Delta T}{T};$$

that is where

$$h = H$$

But $H = 8$ kilometers, about. Hence, the level of constant density is roughly 8 kilometers above sea level, as statistically shown in the papers cited above.

Below this level, density grows greater and above it less, both with the waning of summer and with the increase of latitude; similarly, it grows less below this level and greater above it, both with the passage of winter and with the decrease of latitude.

VARIATIONS IN THE DENSITY OF AIR.[1]

By A. JAQUEROD and C. BOREL.

[Reprinted from *Science Abstracts*, 1921, 24: 217.]

The authors describe briefly some refined determinations of the density of air, made by them at Neuchâtel, with the object of investigating the unexplained variations in the density pointed out by Morley as long ago as 1875. The law of Loomis-Morley is confirmed, namely, that the maximum density is found with samples of air taken when the atmospheric pressure is a minimum, and *vice versa*. Differences of composition do not seem sufficient to explain these variations, and Guye has suggested that the cause is to be found in the presence of ultramicroscopic dust. To test this the authors propose to experiment with air from which dust has been removed electrically. Samples of air obtained by aeroplane from altitudes between 2 km. and 3 km. have been tested and appear to be subject to the same variations of density as the surface air.—*M. A. G.*

[1] *Archives des Sciences*, Paris, Sept.-Oct., 1920, 2: 411-413.

THE ENERGY OF CYCLONES.

[Reprinted from *Nature*, London, March 3, 1921, pp. 11-12.]

In the recent discussion in *Nature* on the energy of cyclones [1] no mention has been made of tropical cyclones, although these are the most remarkable phenomena of their kind.

It is impossible to apply to these cyclones the theories which ascribe the energy of the rotating-wind system to the re-adjustment of equilibrium of warm and cold masses of air within that system, since in the cyclones of the Tropical Zone temperature and humidity are symmetrically distributed. In these cyclones warm and cold sectors do not exist. The Indian meteorologists Henry Blanford, Sir John Eliot, *Fr.* Chambers, and W. T. Willson have published papers on the cyclones of the Bay of Bengal and the Arabian Sea, giving a full explanation of their origin and development. These very important works no longer receive the attention they deserve. They also throw much light upon the source of energy in these cyclones. I endeavored to make a rough calculation of the energy contained within one of these whirls, taking into account the preceding pressure distribution over the hurricane region, and the results were in good agreement with the observed wind forces. I should therefore like to direct attention to this work.

The calculation was based upon observations of the Backergange cyclone. It is given in my *Lehrbuch der Meteorologie* (1901 edition, *p. 579*, footnote), as well as in a paper, "Remarks on the origin of (tropical) cyclones" (*Meteorologische Zeitschrift*, 1877, Aug., p. 311). My calculation has no application to the cyclones of middle and higher latitudes, as it presupposes simple whirls like the symmertical cyclone of the Tropics.—*J. von Hann*, Vienna, Feb., 1921.

[1] Reprinted in Mo. WEATHER REV., Jan., 1921, 49: 3-5.

A REVIEW OF SOME OF THE LITERATURE ON THE SUNSPOT-PRESSURE RELATIONS.

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, May, 1921.]

SYNOPSIS.

In the minds of some meteorologists there is an impression amounting almost to conviction in a few cases that there is a distinct response in terrestrial barometric pressure to changes in solar energy as manifested in the changing spottedness of the sun. This study was carried along in connection with an inquiry into the broader relations of sunspots to terrestrial weather. If there is a distinct response in the pressure then we may expect corresponding changes in the temperature, wind movement, and other meteorological elements.

The evidence submitted by various writers on the subject, beginning with Meldrum in 1872, is examined in as much detail as is now possible and the results reached are given in the "conclusions" at the end of the paper.

At the Brighton meeting of the British Association in 1872, Mr. Charles Meldrum, Director of the Observatory of Mauritius, made the statement that for the area comprised between the Equator and 25° South Latitude, and

the meridians 40 to 110 East Longitude, there appears to be a connection between the frequency of cyclones and of sunspots, which is more than a mere coincidence. The evidence that he submitted seemed to show that there were more cyclones at times of sunspot maxima than at sunspot minima, nearly in the ratio of two to one.

At the next meeting of the Association in 1873, Meldrum presented a carefully prepared list of cyclones in the Indian Ocean for the period of 1847–1873. By grouping these numbers according to frequency of sunspots, he found that in years of maximum spots there were 65 cyclones and in years of minimum spots but 34, or a little more than half of the number in years of maximum spots. In determining the number for any particular spot maximum, he took the sum for the year immediately preceding and following the year of maximum spots. Similarly, the number of cyclones at time of minimum of spots was formed by summing the totals for the central year and the years immediately preceding and following. At this meeting he advanced the proposition that years of spot-maximum should also be years of increased precipitation and thus was started a discussion that has been continued ever since. At that time it seems to have been accepted as an established fact that cyclones were more frequent in years of spot-maximum than in years of spot-minimum.

Poey in 1873 [1] announced that the number of hurricanes in the Antilles and the North Atlantic were more frequent at times of spot-maximum than at spot-minimum, thus confirming the view already expressed by Meldrum. Poey published a list giving the number of hurricanes each year from 1750 to 1873, 357 in all or an average of about two per year.

Considering the obstacles in the way of making an accurate count of the number of hurricanes for this rather extensive region, the difficulty in distinguishing between tropical and extra-tropical cyclones, by reason of the incomplete evidence attainable, it is open to doubt as to whether much confidence can be placed in any list compiled under the conditions which existed in 1873. Even at present it is a matter of some difficulty to make a complete list of the cyclones which traverse the West Indies and contiguous waters. Several such lists have been made. The late Maxwell Hall, Government Meteorologist of Jamaica, published a list of severe storms and hurricanes which visited Jamaica during the 260 years, 1655–1915, in all 31, of which number but 5 are classed as great hurricanes. Dr. O. L. Fassig in Weather Bureau Bulletin X, "Hurricanes of the West Indies," has compiled a list of 143 such storms for the period 1878–1911. Bringing this list down to the year 1919, and extending it back to 1871, for which time the record is fairly complete, we get a total of 174 storms or an average of nearly four storms per annum. This record includes, however, many cyclones of little or only moderate intensity, as evidently does Poey's.

I have examined all three of the records, Poey's, Hall's, and Fassig's, as brought up to date by the writer to see whether or not there is reason to believe that the occurrence of tropical cyclones is related to the sunspot cycle. Poey's method of finding congruence between the two phenomena seems to have been a rather elastic one, that is to say, he did not adhere strictly to the central year of the epoch of maximum or minimum and the single years immediately preceding and following that year as did Meldrum, but, on occasions, he

[1] Comptes Rendus, LXXVII, 1873, pp. 1223-1226.

used the records of as many as three years before and four years after the epoch of maximum and minimum.

Plotting the data of his list against the curve of sunspots, it becomes apparent at once that whatever relation exists, must be an exceedingly loose one. It is true that a number of the epochs of maximum were preceded and followed by more than the usual number of cyclones, but since the average number per year is but two, it must happen that the occurrence of three or four storms in a year of maximum, spottedness may be given equal weight with the occurrence of twice that number. I have rearranged the data of Poey's table in groups of three years each, having as the central year of the group the year in which the maximum or the minimum of spottedness was reached. The table below presents the data arranged consecutively, beginning with the maximum of 1750 and ending with the maximum of 1870; there are, therefore, 12 complete periods of maxima and 11 of minima.

The totals are given in separate columns so that comparison is easily made and always directly with those of the immediately preceding cycle.

(*Poey's table—Comptes Rendus, 77:1226.*)

Maxima.		Minima.		Difference.	
Epochs.	Cyclones, number of.	Epochs.	Cyclones, number of.		
1750.0	6	1755.5	5	− 1	
1761.5	3	1766.5	11	+ 8	
1769.9	5	1775.8	8	+ 3	
1779.5	10	1784.8	15	+ 5	
1789.0	7	1798.5	1	− 6	
1804.0	7	1810.5	11	+ 4	
1816.8	11	1823.2	5	− 6	
1829.5	12	1833.8	8	− 4	
1837.2	22	1844.0	13	− 9	
1848.6	11	1856.2	6	− 5	
1860.2	3	1867.2	3	± 0	End of Poey's list.
1870.7	10	1878.9	10	± 0	
1883.9	8	1889.6	15	+ 7	
1894.1	14	1901.7	13	− 1	
1906.7	12	1913.4	1	−11	
1917.7	20				

The above arrangement shows that comparing 11 complete cycles (Poey) maxima to the immediately succeeding minima, 6 show a larger number of tropical cyclones in years of maxima, 4 the reverse, and 1 result is negative. Expressed in percentages, the numbers are 54 and 34, respectively, or only a little better than an even chance that the number of tropical cyclones will be greater in times of spot maxima than in time of spot minima. Adding to Poey's data those of recent years, compiled by the Weather Bureau, 15 complete cycles become available. The additional data, however, do not materially change the percentages above given. Out of 15 cycles, 8 show a preponderance of tropical cyclones at times of spot maxima, 5 the reverse, and in 2 cycles the numbers are the same.

Attention is directed to the following. In some years of spot maxima, when the number of spots is large, as in 1837, 1870, and 1779, the number of cyclones in the immediately succeeding minimum is relatively large. But this rule does not hold in all cases, thus in the spot-minimum of 1901–1907, following the comparatively weak spot-maximum of 1904, there were 13 tropical cyclones as against 14 at time of spot-maximum. Also in the spot-minimum of 1889 there were 15 cyclones as against but 8 in the immediately preceding spot-maximum. This would seem to indicate that we do not yet recognize the precise means by which the solar influence is transmitted

to the earth and its atmosphere. If only years of relatively great frequency showed this characteristic, it might be inferred that the solar effect is cumulative and is felt several years after the subsidence of the sunspots.

Two other investigators, Prof. F. H. Bigelow and Prof. C. J. Kullmer, have supported the idea that there is a response to solar influence in the paths of terrestrial anticyclones and cyclones.

Bigelow's studies are scattered through a number of papers, but his conception of a change in the movement of cyclones and anticyclones is summarized and illustrated in the *American Journal of Science*, 3rd series, volume **48:** 435–451. This paper has been widely quoted, but in such a way that it is not generally understood, due to the use of terms which are peculiar to the author's nomenclature and, in my judgment, not understood or recognized by meteorologists in general. Bigelow explains in the paper above quoted that he used the weather maps of the years 1882–1893, inclusive, as his basic data. From these he estimated the positions of the centers of HIGHS and LOWS, and divided them into northern and a southern group which were treated independently. By condensing and tabulating the coordinates by years and magnetic periods, he was able to detect any variations in latitude which took place. He adopted the terms North and South High and North and South Low Pressures as descriptive of the two arbitrary groups into which the HIGHS and LOWS of the period had been separated, and he explains the meaning of these terms in the following words (loc. cit.):

The North Low and the South High lines are recognized as the axes of Ferril's Low Pressure belt, which forms a portion of the polar circuit, and the middle latitude high pressure belt, which forms the tropical circuit. The North High track is the average position of the Highs traveling along the polar circuit; the South Low is that of the average position of formation or occurrence of cyclones in the United States. * * * The North High and the South Low tracks are in realty abnormal outgrowths of the atmospheric circulation.

The question is, Do these tracks in general move in latitude during the sunspot period? The result is that the North Low and the South High belts vary in latitude directly with the solar intensity, being farther north at the maximum and farther south at the minimum of the period, while the North High and the South Low belts vary inversely, that is, are farther south during the maximum of sunspots. This means that an increase of solar magnetic intensity generates the cyclones farther south, and causes the anticyclones from the polar circulation to travel to the south.

I have purposely made this rather lengthy quotation because, first of all, Bigelow does not claim that the number of cylones varies directly with the frequency of sun spots, as many writers have assumed, and, second, because a number of meteorologists, unless they have access to the original papers, are in the dark as to what the terms "North and South High and North and South Low" signify.

The direct claim is made that due to variations in solar magnetic intensity lows are generated farther south at the minimum sun-spot period. This claim should be susceptible of statistical proof; it will be taken up later.

Prof. C. J. Kullmer, of Syracuse, N. Y., has made an extensive study of the distribution in latitude of cyclone tracks in the United States and Canada, for the years 1883–1912, as published in the MONTHLY WEATHER REVIEW. This period of 30 years, he has divided into three equal portions and he has charted the distribution of the paths of lows for each 10 years separately. From these charts he finds evidence of a progressive southerly shift in the average paths of LOWS in the United States.

While Prof. Kullmer's method of analysis was correct and the work was evidently carefully done, there were two factors of which doubtless he was not cognizant, which lead me to place a somewhat different interpretation upon his results. These factors are, first, an increase during the period considered in the number of barometer reporting stations in the southwest from which the paths of cyclones in that region are plotted, and second, the lack of homogeneity in the series of storm tracks published in the MONTHLY WEATHER REVIEW, particularly for the earlier years. The establishment of the station at Flagstaff, Ariz., in 1898, Grand Junction, Colo., in 1899, and Modena, Utah, in 1901, led to an immediate increase in the number of LOWS plotted as passing over that region as compared with earlier years.

Moreover, several stations in the Southern Plateau Region which were available in 1883, ceased to function before the opening of the stations above named. The fact that charts of cyclonic paths were made by different officials at different times has already been noted.[2]

Notwithstanding these limitations there was, and is, in certain seasons an increase in the number of secondary cyclones which develop over the Middle and Southern Plateau regions, west of the Rocky Mountains. The mistake should not be made, however, of ascribing the increase to any particular area and not to other adjacent regions. It can be shown that in some years an increase in the number of cyclones passing eastward in the higher latitudes 50°–55°, N., is associated with a general increase in all latitudes considered; in other years a decrease in the number observed in the higher latitudes is associated with an increase in some of the latitudes farther south, and in others a decrease. The following examples illustrate the two extremes in distribution.

Departures from average of Lows Crossing the 100th meridian in the latitudes named.

Latitude.	1893	1897	1902	1911	1918
55 to 50 North	+9	+9	−16	−21	+13
50 to 45	+3	−5	− 6	+ 3	+ 4
45 to 40	+7	−4	− 3	+ 6	+ 1
40 to 35	+6	−4	+ 1	+ 5	+ 4
35 to 30	+2	−3	+ 7	− 3	+ 8
30 to 25	−5	−2	....	− 2	+ 3

Dr. H. Arctowski[3] has tabulated the number of LOWS crossing the 100th meridian in the latitudes corresponding to the above for the years 1883–1913, and I have brought the figures down to include 1920, thus giving a 38-year continuous record. The means for the various steps in latitude have been computed, whence are derived the departures above given. Arctowski's summation shows that on the average more LOWS cross the 100th meridian between 35° and 40° north latitude than in the 5-degree square immediately to the north. The completed table for the 38 years also gives the same result, the averages being 18 LOWS per year at north latitude 40°–45° and 21 LOWS at north latitude 35°–40°. Hence there is not, on the average, a progressive decrease in the number of LOWS crossing the 100th meridian with decrease in latitude.

In another compilation that I have made after the method of Kullmer, it is shown that there is a decided excess of LOWS in the 5-degree squares between 35°–40° north latitude and 95°–115° west longitude, as compared with similar squares between 40°–45° north latitude and the same longitude. A similar result can be seen in the work of Bowie and Weightman, Weather Bureau Supplement No. 1, and these authors indicate the probable

[2] MO. WEATHER REV., Aug., 1915, 43: footnote page 374.
[3] MO. WEATHER REV., Aug., 1915, 43: 384.

explanation on page 7 of SUPPLEMENT No. 4, 1917. The cyclones which develop over the Middle Plateau Region, or move thereto from the northwest, belong to the Colorado type which has a very prominent seasonal distribution, reaching its yearly maximum in March and its minimum in September. It should be kept in mind, therefore, that an increase in the number of the Colorado LOWS in the spring and autumn is to be expected and this increase should not be confounded with a diminution of the number of LOWS in some other latitude, or explained as a latitude shift in storm paths.

Attention has often been called to the fact that when for any reason the eastward progress of a primary Alberta or North Pacific LOW, situated west of the Rocky Mountains is interrupted, a secondary LOW develops over the Southern Plateau. Strictly speaking, then, in all these cases there is not an increase in the number of cyclones, but rather an increase of cyclone activity in southern latitudes and a corresponding decrease in more northern latitudes, the net result of which, according to the rough measures available for counting the number of individual cyclones, is to show an apparent increase in some years as compared with others. Finally, what is the evidence of the statistics of LOWS crossing any given meridian in the United States, admittedly incomplete as they are, with respect to the question of an increase in the number of cyclones corresponding to the period of maximum sunspots?

I have smoothed the annual number of cyclones crossing the 100th meridian, using Arctowski's count 1883–1913, and my own 1913 to 1920, and plotted the smoothed numbers in connection with the smoothed sunspot numbers in figure 1 below.

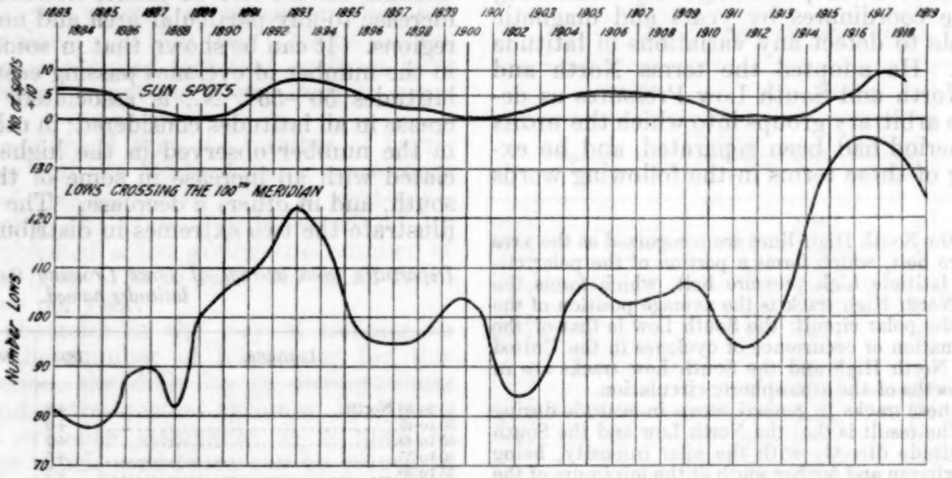


FIG. 1.—Relation of sunspot numbers to the number of LOWS crossing the 100th meridian, 1883 to 1919, inclusive.

As may be seen from this figure there is good correspondence in the two curves at spot-maximum of 1894 and 1917, respectively, only fair correspondence at spot-maximum of 1906, and very little correspondence at spot-maximum of 1883.

While the curve for the United States for the years 1891–3 shows that a large number of cyclones crossed the 100th meridian, the data for the West Indies do not show a like increase in the number of cyclones in those years. And, moreover, if we take the 80th meridian of West Longitude, instead of the 100th, as our point of reference, we arrive at a distinctly different result, viz, the great peak in the curve of LOWS crossing the 100th meridian in the years 1914–1919 practically disappears. The actual count for the two meridians follows:

Year.	Meridians. 100	Meridians. 80	Difference 100-80.
1914	114	103	11
1915	134	107	27
1916	138	108	30
1917	134	102	32
1918	137	104	33
1919	124	104	20
1893	127	102	25
1894	123	102	21

Hence it appears that the large number of LOWS crossing the 100th meridian in the years above enumerated which fact might readily be interpreted as indicating a response to cosmical influences is after all dependent upon terrestrial atmospheric phenomena, perhaps modified to some extent by the relief of the Southern Plateau. Using the figures of Arctowski's table (loc. cit.) for 1893 and 1894, and inserting them at the bottom of the above table it is seen that the same condition held in those years as in the later series; hence what at first seemed to be a confirmation of the proposition advanced by Meldrum and others is, on further inquiry, clearly a result of terrestrial conditions rather than cosmical.

The number of cyclones in the West Indies was at a maximum in 1886, 1900–01, and 1916. This is interpreted as evidence of terrestrial control in both regions.

CONCLUSION.

In that part of the Indian Ocean investigated by Meldrum there is convincing evidence that the number of cyclones was greater in years of sunspot maximum than in years of sunspot minimum. No evidence has been submitted or sought to show that the excess in question could not have been explained on terrestrial grounds.

The evidence of the West Indies and the southern portion of the North Atlantic is not convincing either way, although there are indications that the number of cyclones at and near the years of spot-maximum is greater than in years of spot-minimum.

The data for the United States show that an increase or decrease in the number of LOWS is primarily due to the pressure distribution over extensive areas, the co-called "action centers" probably modified to some extent by local atmospheric conditions, which result from orographic control (fig. 1).

VAPOR PRESSURE AND HUMIDITY DIAGRAM.

By ROBERT E. HORTON.

[Voorheesville, N. Y., Jan. 5, 1921.]

For many of the practical and commercial uses of humidity observations, results giving dew-point temperatures to the nearest degree, and relative humidity within 1 or 2 per cent of the true value, are sufficiently accurate. The determination of the dew point and relative humidity by means of psychrometric tables from wet and dry bulb readings requires the use of two separate tables and involves separate operations. If only air temperature and relative humidity are given, then to determine vapor pressure and dew point some calculation is required in addition to the use of tables.

Various diagrams for the solution of problems involving humidity have been prepared, but in general such diagrams are necessarily large in order to provide sufficient accuracy, and, furthermore, separate diagrams are usually required for reduction of psychrometric readings for the determination of humidity and dew point.

In a recent paper,[1] L. S. Hall has described a simple graphical method by means of which many curves, empirical and otherwise, can be reduced to straight lines. This is accomplished by the use of a varying scale for one of the coordinates. Applying this method to the temperature scale of an ordinary curve of maximum vapor pressures, a rectilinear vapor pressure line is obtained. This is shown by the diagonal line designated "Vapor Pressure" on figure 1. Vapor pressures in inches are given by a uniform scale underneath this line and at the base of the diagram, and temperatures by a varying scale at the right of the diagonal line. An advantage of this method of plotting as compared with the reduction of such curves to straight lines by logarithmic or other scales is that the latter in this instance give decreasing temperature scale intervals as the vapor pressure increases, whereas the method here used gives an increasing temperature scale with increased vapor pressure, thus facilitating accurate reading of the results from the diagram.

Since, with the scale system here used, the maximum vapor pressure line is straight, it follows that the vapor pressure lines for various percentages of relative humidities are also straight lines. These are represented by the radial diagonal lines to the left of the vapor pressure scale. Thus far the diagram affords a basis for direct reading of maximum vapor pressure at a given temperature, of relative humidity for any given temperature, and absolute vapor pressure, or of actual vapor pressure, for any temperature and relative humidity. In order to provide a complete graphical solution of humidity problems, it is desirable to include on the diagram means for the determination of the dew point from wet-and-dry-bulb-thermometer readings. For a given air or dry-bulb temperature, the dew-point temperature decreases as the depression of the wet-bulb increases, or, in other words, as the reading of the wet-bulb thermometer decreases. To express these relations, a horizontal scale of wet-bulb readings has been placed at the base of the diagram, and curved guide lines drawn such that the dew-point temperature is found on the temperature scale at a point horizontally opposite the intersection of the guide line for a given dry-bulb reading with the vertical scale ordinate through the given wet-bulb reading. The following examples illustrates the use and accuracy of the diagram:

Given wet-bulb reading 54°, and air temperature or dry bulb 60°, to find the dew point, vapor pressure, and relative humidity for 30 inches barometric pressure. The dew point is given on the temperature scale at "*b*," opposite the intersection at "*a*" of the guide line for dry-bulb reading 60°, with the vertical line through wet-bulb reading 54°, or 49°. Extend this line horizontally to the left of its intersection with the temperature diagonal—the vapor pressure is given vertically underneath the point "*d*" at "*e*" on the vapor-pressure scale, or 0.34 inch, and the relative humidity is given vertically above the intersection point "*d*," at the intersection of this vertical line with the 60° horizontal temperature line at "*f*," or 66 per cent.

The operation is very simple, since the three required values are found from two intersections, and two of them are on the same vertical line. The operation of determining the depression of the wet-bulb which is necessary in the use of psychrometric tables is here avoided.

Given the air temperature and humidity to find the vapor pressure and dewpoint—for example, with air temperature 83°, and relative humidity 67 per cent. Enter at 83° on the temperature scale. Run horizontally to the left to the intersection of this line with the relative humidity at the point "*f*," vertically underneath at "*g*" read the temperature of the dewpoint 71° on the temperature scale, and read the vapor pressure 0.76 on the vapor-pressure scale at the bottom of the diagram.

Given the air temperature and dewpoint, to find relative humidity. With air temperature 43° and dewpoint 37° at the intersection "*k*" of the horizontal line, through 43° on the temperature scale with a vertical through "*i*," corresponding to dewpoint temperature 37° on the vertical scale, read the relative humidity 80 per cent on the diagonal at "*k*," and the vapor pressure 0.22 at "*m*," vertically underneath the vapor-pressure scale.

As illustrating the accuracy of the diagram, the problems listed in the subjoined table were solved for wet- and dry-bulb readings, as indicated in the column headings. The correct values as determined from the psychrometric tables are given in column 2 in each instance.

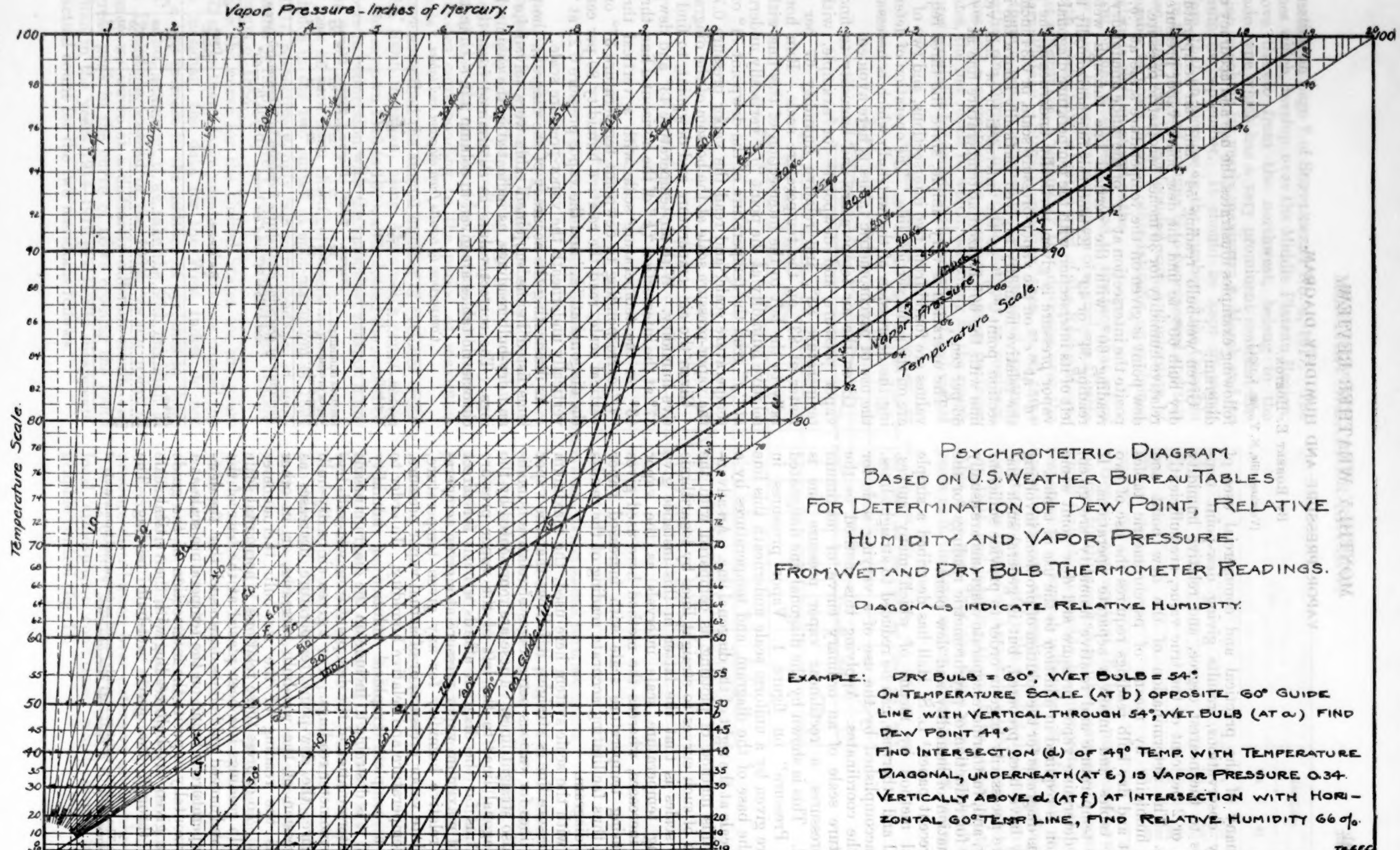
Comparison of results from diagram and tables.

	°F.		°F.		°F.	
Dry-bulb=	70		60		80	
Wet-bulb=	51		44		76	
	Diagram.	*Tables.*	*Diagram.*	*Tables.*	*Diagram.*	*Tables.*
Relative humidity	22	22	22	21	83	83
Vapor pressure	.160	.164	.115	.108	.840	.838
Dewpoint	29	30	22	21	74	74

Variation of dewpoint and relative humidity with barometric pressure for wet-bulb=54° and air temp. (Dry-bulb)=60°.

Barometer.	Dew-point.	Relative humidity.
Inches.	°*F.*	*Per cent.*
30	49	68
29	49	68
27	50	69
25	50	70
23	50	71

[1] Hall, L. S: The probable variation in yearly run-off as determined from a study of California streams. *A. S. C. E. Papers and Discussions*, 1920.


Vapor Pressure - Inches of Mercury.
Temperature Scale.
Wet Bulb Reading and Vapor Pressure × 100
Temperature Scale
Vapor Pressure
Guide Line
PSYCHROMETRIC DIAGRAM
BASED ON U.S. WEATHER BUREAU TABLES
FOR DETERMINATION OF DEW POINT, RELATIVE
HUMIDITY AND VAPOR PRESSURE
FROM WET AND DRY BULB THERMOMETER READINGS.
DIAGONALS INDICATE RELATIVE HUMIDITY.
EXAMPLE: DRY BULB = 60°, WET BULB = 54°.
ON TEMPERATURE SCALE (AT b) OPPOSITE 60° GUIDE
LINE WITH VERTICAL THROUGH 54°, WET BULB (AT a) FIND
DEW POINT 49°
FIND INTERSECTION (d) OF 49° TEMP. WITH TEMPERATURE
DIAGONAL, UNDERNEATH (AT E) IS VAPOR PRESSURE 0.34.
VERTICALLY ABOVE d (AT f) AT INTERSECTION WITH HORI-
ZONTAL 60° TEMP. LINE, FIND RELATIVE HUMIDITY 66 %.
TR.GEC

The diagram is prepared primarily for barometric pressure 30 inches. Results will be sufficiently accurate for most practical purposes whenever the barometric pressure is not less than 27 inches. The variation of dewpoint and relative humidity with barometric pressure is illustrated for the case of dry-bulb reading 60° and wet-bulb 54° in the subjoined table.

Most evaporation formulas, including that of the author, involve the maximum vapor pressure at the temperature of the evaporation surface, and the actual vapor pressure in the air, as factors. The diagram is especially adapted to the determination of these quantities, either from observational data where the dry-and-wet-bulb readings are given, or from published data where either the air temperature and relative humidity, or air temperature and dewpoint, are given.

A PSYCHROMETRIC CHART FOR DETERMINING THE DEWPOINT AND RELATIVE HUMIDITY.

By R. B. SMITH, C. E.

[1997 Vinewood Ave., Detroit, Mich., Feb. 19, 1921.]

Psychrometric observations are usually reduced by means of tables computed from some formula for the pressure of aqueous vapor in the air and from the known values of this pressure for saturated air. It is entirely feasible to perform this reduction graphically without the use of tables by means of a chart constructed according to the following principles:

(1) The addition of two quantities which can be represented with sufficient accuracy on a suitable scale can be effected graphically by laying a straight edge between two scales on which the two quantities are plotted and reading the value where the straight edge crosses a third scale, midway between the other two, in units one half as large as those used in plotting the quantities to be added, provided all three scales have their zero values on a straight line. This is clear from Fig. 1, in which a and b represent the quantities to be added and $a'+b'$ represents their half sum for all values of a and b.

(2) The subtraction of one quantity from another can be effected graphically by the same operation, provided the quantity to be subtracted is plotted in a direction opposite to that of the other two scales, as shown by Fig. 2, where evidently $a'-b'$ represents half the difference between a and b for all values of a and b.

(3) Multiplication or division can be performed graphically by substituting, for the numbers representing the quantities to be added or subtracted, their logarithms.

Fig. 3 illustrates the application of the foregoing principles to the graphical reduction of psychometric observations by a solution of the formula

$$e-e'-.00066\ B\ (t\text{-}t')\ (1+.00115\ t').$$

The factor B is incorporated in the solution as follows: If a, Fig. 3, represents a value of $.00066\times 760\ (t\text{-}t')$, b the value 760 and b' the value of B, then $a'=B\ (t\text{-}t')=$ 760B (t-t')/760, since $a':b::a:b$, or $a'=ab'/b$.

The relative humidity is determined by measuring directly the difference between the values of log e', figure 3, corresponding to the temperature of the air and the temperature of saturation (dewpoint) respectively and subtracting this difference from the value of log 100.

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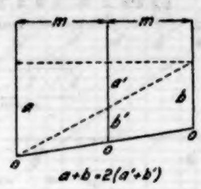
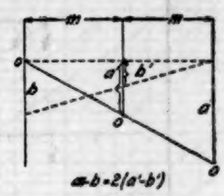
The chart when ready for use in reducing observations is simply lettered with the values of the psychrometric data corresponding to the values on the scales and with notes giving an explanation of the procedure to be followed



a+b=2(a'+b')
Fig. 1.



a-b=2(a'-b')
Fig. 2.

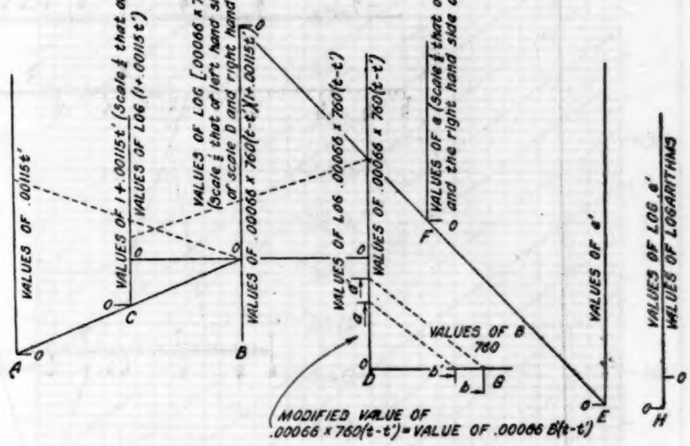
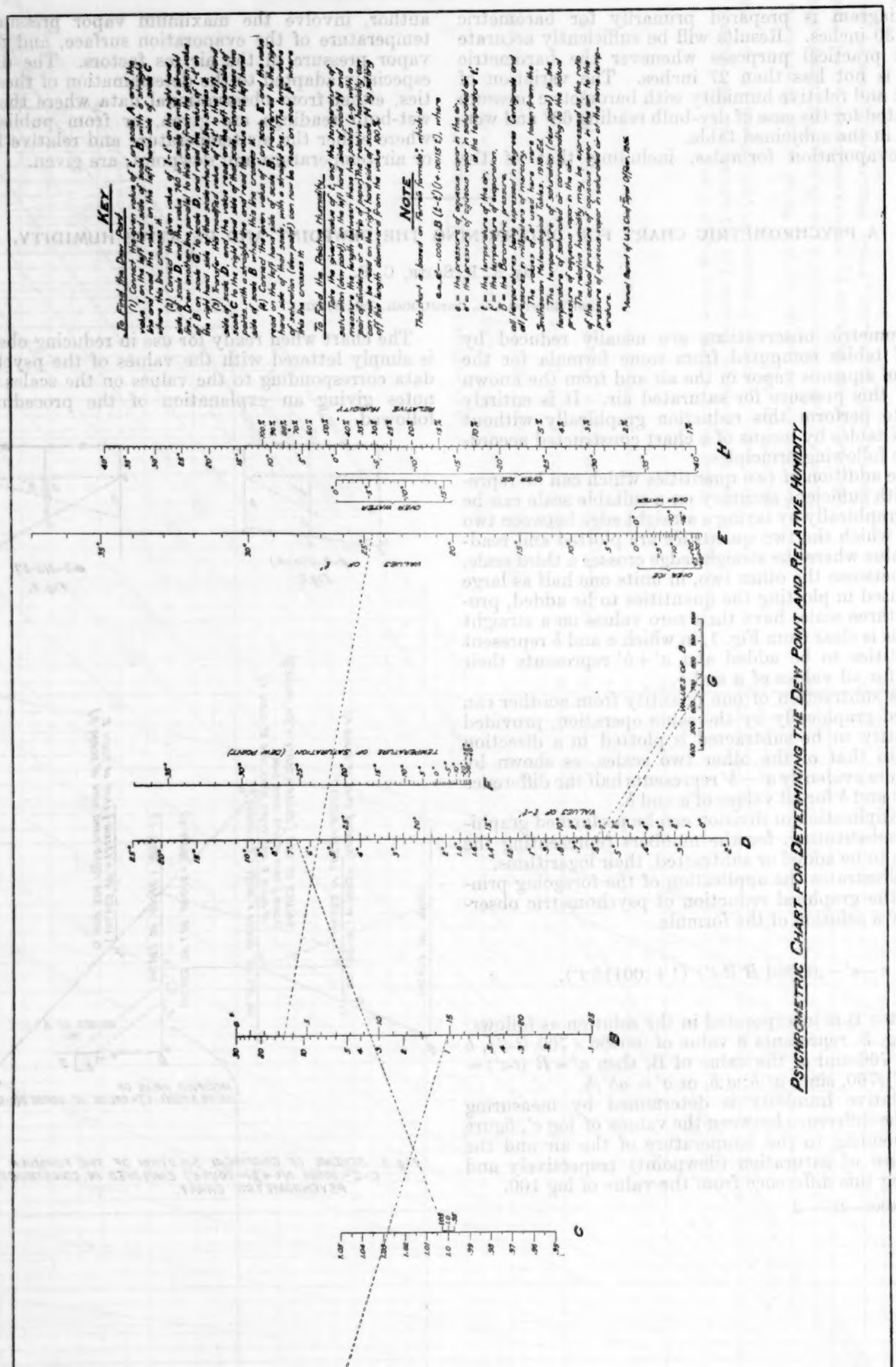


Fig. 3. SCHEME OF GRAPHICAL SOLUTION OF THE FORMULA C=C'-.00066 B(t-t')(1+.00115 t') EMPLOYED IN CONSTRUCTING PSYCHROMETRIC CHART.

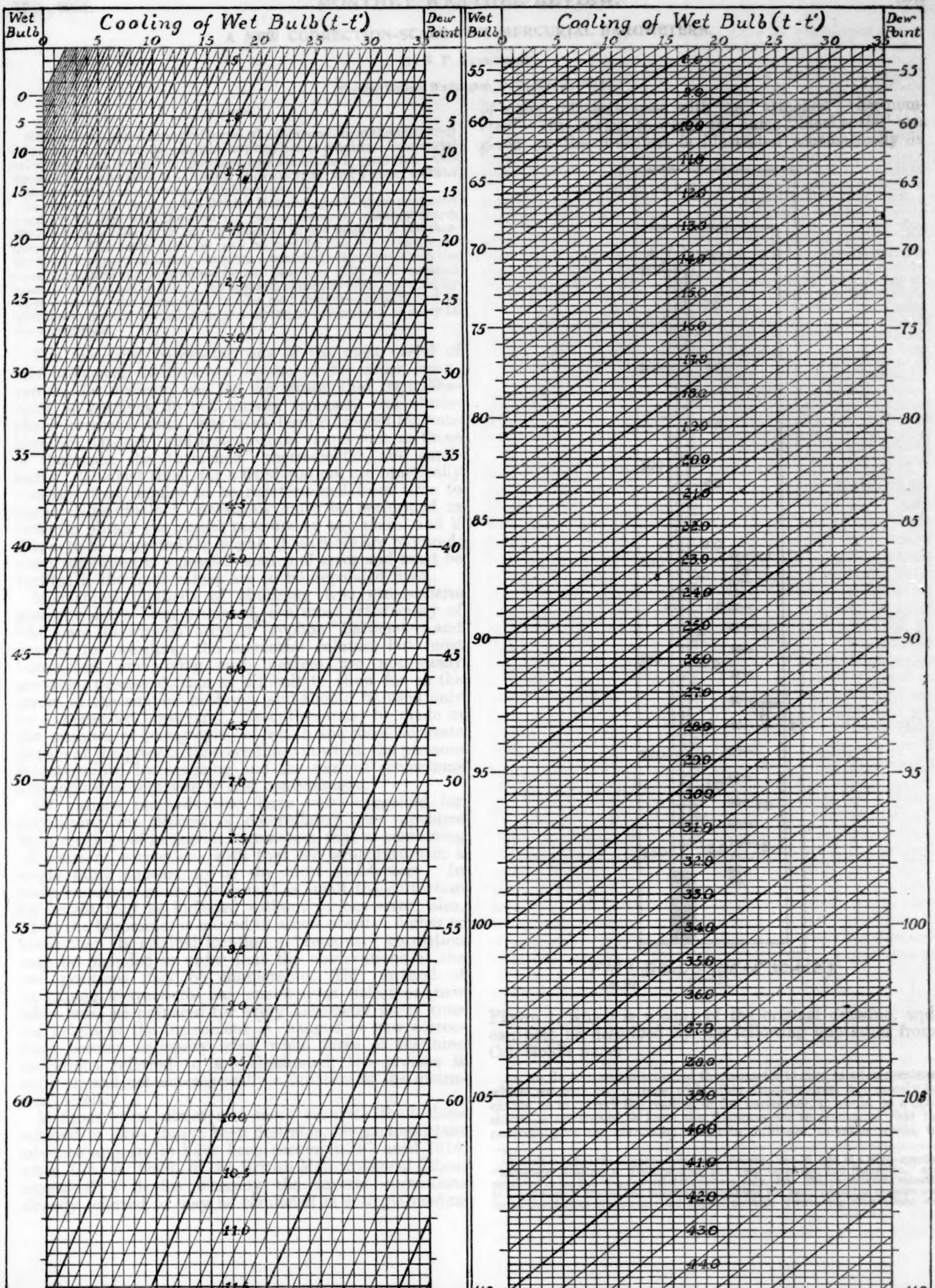

PSYCHROMETRIC CHART FOR DETERMINING THE DEW POINT AND RELATIVE HUMIDITY
KEY
NOTE
A
B
C
H

#140/2

PSYCHROMETER CHART (MARVIN)

U. S. WEATHER BUREAU

AMOUNT OF VAPOR, GALLONS PER 100,000 CU. FT.



A NEW CORRECTION-SCALE FOR MERCURIAL BAROMETERS.

By S. P. FERGUSSON.

[Weather Bureau, Washington, D. C., June 20, 1921.]

SYNOPSIS.

Corrections, for instrumental errors, the temperature of the mercurial column and for latitude, must be applied before readings of mercurial barometers can be used to represent true atmospheric pressures. Obviously, each operation is a possible source of error, and a direct method of determining correct values is highly desirable.

In 1914, Col. E. Gold, of the British Meteorological Office, suggested a scale to be used with the attached thermometer, by means of which the corrections referred to can be obtained in one reading of the thermometer. This scale, however, can be used for but one pressure; in the present paper the author describes a modified scale from which the same corrections can be obtained for any pressure. The final corrected pressure is obtained in five or less operations instead of six required by other methods, the corrections can be read more accurately, and in addition to the time saved there is a saving of one column of entry in the record-form.

The mercurial barometer, one of the most useful of meteorological instruments, is one of the most inconvenient for ordinary use for the reason that its indications or readings do not usually represent true atmospheric pressures until they have been corrected for temperature, latitude, and instrumental errors such as those of the scale, the "attached" thermometer, and capillarity. The last three, for a fixed station, are practically constant, but require to be redetermined from time to time. Nine distinct operations must be performed in order to obtain the actual pressure at any place, and if this is to be corrected for height, three more are required; every operation is a possible source of error and must be verified if the final values are to be depended upon.

Mechanical methods of obtaining true atmospheric pressures have been proposed, the most satisfactory of which are the various forms of "syphon" barometers and devices for weighing the mercurial column; but most barometers embodying such devices are not easily portable, possess defects as difficult to allow for as the errors of the simpler patterns, and should be used only by experienced observers. Exception must be made in the instance of barographs, of which the most accurate known at the present time are those in which the pressure is determined by weighing and the various corrections are applied automatically and continuously.

Of various methods that have been suggested for simplifying the process of determining true pressures from readings of mercurial barometers, that of combining all constant corrections with that for temperature in a single table appears to be the most satisfactory. In some instances where the height is small the correction for height may be included without serious error; also, when the barometer is moved to a new position higher or lower than its original location a "removal" correction may be included in order that the observations at the two positions may be comparable. This method of combining corrections has one serious defect—a new table must be prepared for every barometer every time the height of the instrument is changed or new corrections become necessary; also, while three of the nine operations referred to are eliminated, the process is indirect, and not automatically a function of the instrument itself.

Methods more direct and more accurate than those referred to have always been desirable, but no important advance appears to have been accomplished until 1914, when Col. E. Gold, of the British Meteorological Office, suggested a device whereby the several corrections already referred to may be combined in a single reading of a movable scale used with the "attached" thermometer.[1] This device, to which the name "ideal scale" was given by the inventor, is illustrated schematically in

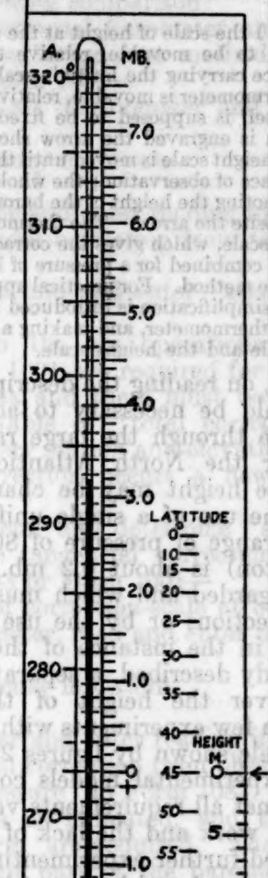


FIG. 1, (GOLD'S "IDEAL" SCALE.)
S.P.F. 1921. (1914.)

Figure 1, which is a copy of the original drawing, and can best be described by the following quotation from Col. Gold's paper:

> As we do not use an attached thermometer to give us a temperature which we wish to compare with other temperatures, but merely to enable us to correct the reading of the barometer, it would be a considerable advantage to have the thermometer so graduated that its readings gave the correction direct in millibars; in other words, to

[1] Described before the Royal Meteorological Society, May 20, 1914, in a paper entitled "Barometer Readings in Absolute Units and Their Correction and Reduction," and published in the *Quarterly Journal* of the Society, July, 1914. This paper is very valuable as a summary of present-day information regarding the measurement of pressure and for its descriptions of ingenious and original methods of correcting observations, etc.

make a thermometer for which each scale division corresponded with a correction of 0.1 mb. for a reading of 1,000 mb. The divisions would be about 10 per cent further apart than the divisions for degrees Fahrenheit. Such a thermometer is shown in the diagram (fig. 1). It would be especially advantageous for use at a fixed station at a low level or for a barometer at sea, because, by an appropriate adjustment of the scale by which the thermometer is read, the combined correction would be read off directly from the instrument.

For a fixed station the scale would be set once for all at the appropriate latitude and altitude. It could then be clamped and the observer would thenceforward simply take his barometer reading and read off the necessary correction from the 'thermometer.'

The correction would need modification only if the pressure differed considerably from 1,000 mb.; usually, the correction, as read would be sufficient.

* * * In figure 1 the scale of height at the right-hand side of the diagram is supposed to be movable, relative to the latitude scale; while the whole piece carrying the latitude scale and the ideal scale for the attached thermometer is movable, relative to the thermometer. The thermometer itself is supposed to be fixed to the frame of the barometer, on which is engraved the arrow shown at the right. To set for a reading, the height scale is moved until the "0" comes opposite the latitude of the place of observation; the whole piece is then moved until the number denoting the height of the barometer cistern M. S. L. in metres comes opposite the arrow. The thermometer reading is then taken from the ideal scale, which gives the correction for temperature, gravity, and altitude combined for a pressure of 1,000 mb. This illustrates the theory of the method. For practical application Mr. Whipple has pointed out that simplification is introduced by fixing the latitude scale, relative to the thermometer, and making a single movable piece bearing the ideal scale and the height scale.

It was obvious, on reading the description thereof tnat modification would be necessary to adapt the original ideal scale to use through the large ranges of pressure experienced near the North Atlantic coast or with barometers whose height may be changed. The error resulting from the use of a single uniformly graduated scale through a range of pressure of 80 mb. (the range recorded at Boston) is about 0.2 mb., a quantity too large to be disregarded and which must be allowed for by applying corrections or by the use of a mechanical adjustment. As in the instance of the table of "total correction" already described, a separate scale would be necessary whenever the height of the barometer is changed. After a few experiments with adjustable scales the tangential scale shown by figures 2 and 3 suggested itself and two experimental models constructed during November 1914 met all requirements very satisfactorily. Pressure of other work and the lack of a suitable ruling machine prevented further experimenting until recently, and the few scales produced have not been tried outside the laboratory; but it is believed that the pattern described herein is not likely to require important modification unless in the direction of greater simplicity.

Assuming that the barometer in use is the well-known "standard" of either Fortin or Kew pattern, and of good quality, the most important of the operations incidental to obtaining true pressures from its readings is that of determining the correction for temperature. This is zero at a certain temperature, which is 0° C. for the International and 28.5° F. for the English scale, at all pressures, and obviously its value at higher or lower temperatures is directly proportionate to the length of the barometric column. The construction of a correction-scale for any definite pressure, such as 1000 mb., has been described in the quotation from Col. Gold's paper. A scale for any range of pressure, as, for example, that of 900 to 1000 mb., is obtained in the following manner: First, the distance, from the common zero, of an extreme value, such as 5.0 mb., at each of these pressures, corresponding to the equivalent reading of the thermometer used is marked on the blank to be ruled; next, this space is divided, by two parallel columns of dots (one for each pressure), at any suitable distance apart. By ruling lines connecting dots representing the same value, we produce the tangential scale (B) shown in figures 2 and 3. The lines are

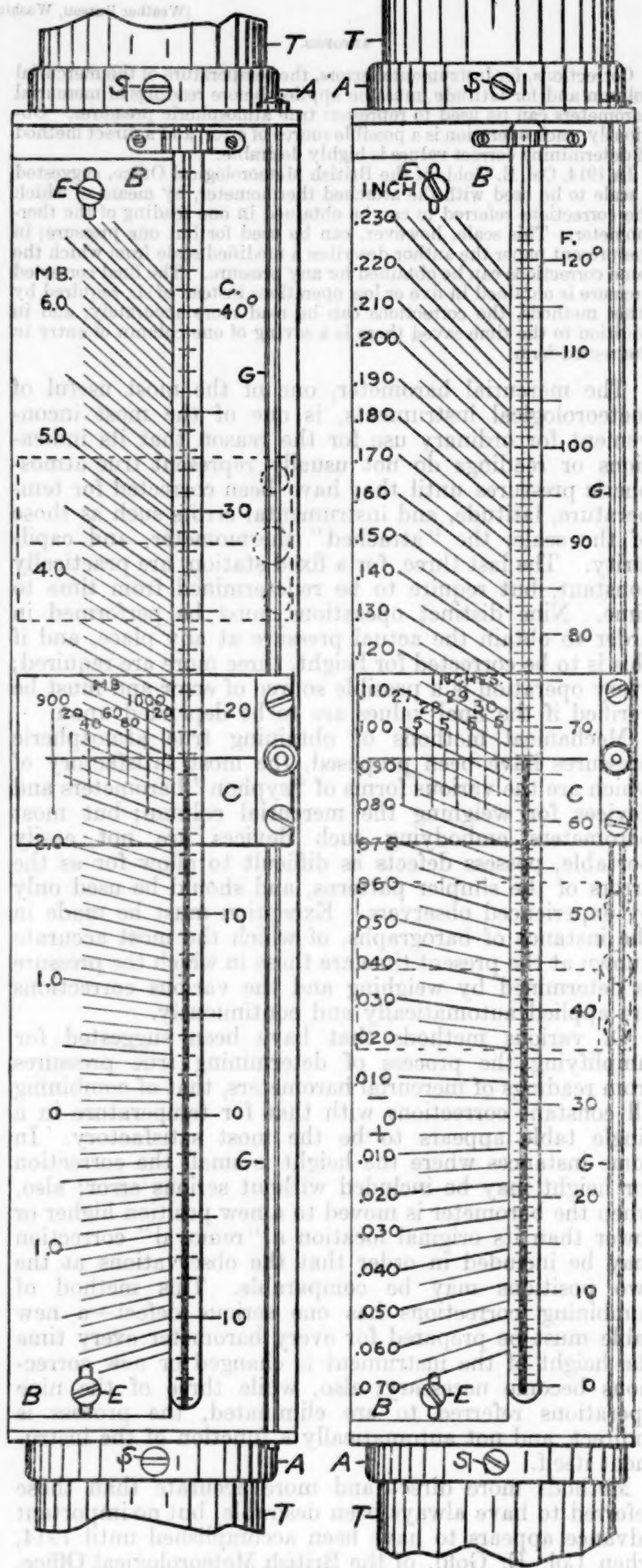


FIG. 2, (MILLIBARS) FIG. 3, (INCHES)

S.P.F., 1914.

uniformly spaced, but since the values of corrections for low pressures are smaller than those for higher pressures, the distance between the lines must be progressively larger as the pressure decreases. Referring to figure 2, the temterature equal to a correction of 5.0 mb. at a pressure of 1000 mb. is 30°.5 C.; that for a pressure of 900 mb. is 33°.8, or, otherwise expressed, the correction at 900 mb. for a temperature of 30°.5 is 4.5 mb. instead of 5.0 mb., the value for 1000 mb. To obtain values for pressures between 900 and 1000 mb. vertical lines for any interval desired can be ruled on the scale itself, or preferably, as shown, on a transparent index-plate (C), which can be adjusted and possesses the further advantage that the numbers of the vertical lines are always near the central index-line, where the readings are made. The index (C) slides on a guide (G) parallel to the scale (B) and the thermometer tube. The various parts are secured to a base (A), fitted and clamped to the outer metal tube of the barometer (T) by screws (S). To obtain corrections the central horizontal line on the index-plate (C) is set at the top of the thermometric column and the correction read at the point representing the current pressure; as shown in figure 2, where the temperature is 17°.8, the correction for a pressure of 985 mb. is −2.82 mb. In figure 3 the correction for a temperature of 66°.7 and a pressure of 29.51 inches is −0.1015 inch. Allowance for constant errors or corrections already referred to is accomplished as follows, the values given indicating the method only:

Correction for instrumental error	+0.15 mb.
Mean correction applied to attached thermometer, −0.2°, equal to	+0.25 mb.
Correction for latitude	−1.12 mb.
"Removal" correction	+0.92 mb.
Total correction	+0.20 mb.

This value, thereafter, is automatically added to all readings by moving the scale (B), until its zero is 0.20 mb. below the zero of the attached thermometer (0° C.), and clamping it in position by means of the screws (E), (E). If, for example, the total constant correction indicated is to be added to the correction for temperature already obtained in the example shown for figure 2, the final value will be −2.62 instead of −2.82.

It is obvious that even if the ordinary "attached" thermometer with a short scale is employed, these correction-scales may be ruled direct to 0.1 mb. or 0.005 inch, and values to 0.01 mb. or 0.0005 inch estimated with considerable precision, an accuracy impossible with the ordinary table of corrections determined for intervals of half degrees and ten millibars or half inches. Even in the extreme case of the use of a mountain barometer, where the correction-scale may be much compressed and the diagonal lines at high temperatures are very steep, the errors are smaller than those of the tables described. Obviously, if there is no objection to increasing the bulk of the instrument, the tangential scale (B) can be made wider and ruled to fit a thermometer with a long scale; but this is unnecessary except in the instance of a standard barometer where readings of extreme precision are desired. Ordinarily, the tangential correction-scale need not occupy appreciably more space than does the usual "attached" thermometer.

When used with a barometer carried to great heights, where the pressure may be as low as 400 mb. one side of the scale-plate (B) may be ruled for pressures between 1050 and 600, and the other for pressures below 700 mb., and the clamp screws (E), (E), so placed that the scale will be in the proper position with either side in use. The vertical lines on the transparent index-plate (C) will serve for both sides of (B), and only require to be numbered at the top for one scale and at the bottom for the other. Ordinarily, however, only one ruling will be needed for the average "station" barometer at any height below 3,000 meters.

Differences between the customary method of reading the barometer and correcting the observations by a table and that provided by the new correction-scale are shown in the following comparison:

To read the mercurial barometer and determine the "station" pressure by present method, recording data in Form 1083 or form 1001—

(1) Read attached thermometer and enter reading in Form 1083.
(2) Adjust mercury in cistern.
(3) Set vernier.
(4) Read vernier and enter reading in Form 1083.
(5) Ascertain total correction from table and enter in Form 1083.
(6) Apply correction and enter "station" pressure in Form 1083.

In addition to the six operations indicated, four columns in Form 1001 are required for the observations and corrected data and there must be accessible at all times a special table of "total correction" for every barometer and every station and elevation; if any change of height or correction occurs a new table must be prepared.

To read barometer and determine "station" pressure by means of the tangential correction-scale, recording data in Form 1083 or Form 1001—

(1) Set index of correction-scale at current reading of attached thermometer, read and enter total correction in Form 1083.
(2) Adjust mercury in cistern.
(3) Set vernier.
(4) Read vernier and enter reading in Form 1083.
(5) Deduct total correction from observed reading and enter "station pressure" in Form 1083.

Five operations as indicated, and three columns or spaces in the form are required. The correction-scale forms a permanent part of the barometer, is instantly adjustable to any change of the corrections, and is ready for use at any height. No separate table of corrections necessary.

Examples of entries in Form 1001, in English and International units when present method is employed:

International units.				English units.			
Attached therm.	Observed reading.	Total correction.	Station pressure.	Attached therm.	Observed reading.	Total correction.	Station pressure.
18.8°	988.55	−2.87	985.68	66.7°	29.922	−0.103	29.819

When new correction-scale is employed:

International units.			English units.		
Observed reading.	Total cor'n.[1]	Station pressure.	Observed reading.	Total cor'n.[1]	Station pressure.
988.55	−2.87	985.68	29.922	−0.1025	29.819

[1] From correction-scale—read and entered first.

The classification of operations adopted may be objected to for the reason that three items are included in the operation of obtaining the correction from the scale; but actual comparison shows that much more time is consumed and there is larger probability of error in the use of a loose table, particularly when double interpolation becomes necessary, than is the case with the new correction-scale.

In the extremely rare instance of the need of the temperature of the attached thermometer, this can be ascertained in a few seconds by deducting the constants from the total correction as recorded and looking up the equivalent temperature.

The preceding description and comparison may be summarized as follows:

(1) The tangential correction-scale described is a means of determining the true pressure from observations of a mercurial barometer wherever it may be used, without the use of a separate table of corrections which may be lost or mislaid and is always an inconvenience. This scale forms a part of the barometer, as does the customary attached thermometer which it is intended to replace.

(2) The scale can be adjusted to allow for constant errors or corrections and the total correction obtained in one reading of the attached thermometer. Any change of correction is allowed for by a simple adjustment, and no adjustment is required for a change of height.

(3) The number of operations required to obtain the "station" or actual pressure is smaller and the whole process simpler than is the case when the customary separate table of correction is employed.

(4) Corrections for barometers of the ordinary or station pattern can be read to 0.01 mb. or 0.0005 inch at intervals of 5 mb. or 0.05 inch; when barometers of precision with wide-scale thermometers are used smaller values are easily obtained. Equal precision can be secured only by the use of special tables.

(5) Errors in reading the attached thermometer, usually very difficult to detect, are entirely eliminated by the use of the scale, the index line of the transparent scale being set at the top of the thermometric column when a reading is to be made.

(6) Errors in estimating values on the tangential scale are not so easily made nor are they so important as errors in interpolating from the usual printed table of corrections.

(7) When the correction-scale is employed the column in Form 1001 for readings of the attached thermometer becomes unnecessary. The extremely rare instances where this temperature is desired are easily provided for by ascertaining the temperature corresponding to any correction.

(8) As shown in the figures, the new correction-scale is constructed as a complete unit that may be secured to the outer tube of the barometer in the position usually occupied by the attached thermometer and in the same manner. When the distance between the two screws (S), (S), (figs. 2 and 3) is known, the scale-base (A) can be bored accordingly and the correction-scale, complete, shipped to a distant station to be attached by the observer; it will not usually be necessary to send barometers to a central point or a shop when scales are to be fitted or changed.

(9) The new correction-scale increases the cost of the barometer slightly, but it is believed that the advantage and convenience of having the means of correcting the readings form an inseparable part of the barometer itself will more than outweigh the additional cost.

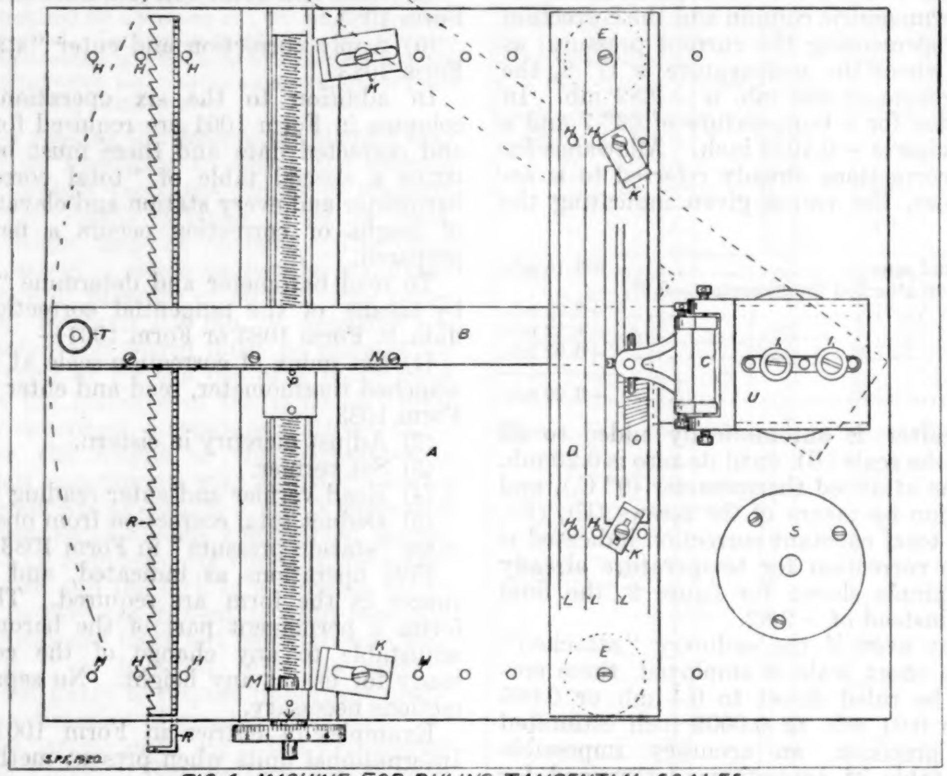


FIG. 4. MACHINE FOR RULING TANGENTIAL SCALES.

The accuracy required in ruling the tangential scales is easily attained by the ordinary dividing engines usually found in shops and laboratories; but, because of the peculiar character of the ruling required, the graduation can be performed much more easily and with greater rapidity by means of the special dividing machine shown

in Figure 4. This apparatus consists essentially of a pivoted bar (B), carrying an ordinary ruling mechanism (C), a plate (D), upon which is secured the blank to be ruled, and means for spacing which may be either the micrometer (M), or the ratchet rack (R). These parts are mounted on a substantial cast-iron base (A). To rule a tangential scale, the limits of the space to be ruled and the distance between the zero and some extreme value, such as 5.0 mb. (determined by reference to the thermometer to be used), are marked on the blank which is placed on the plate (D) and so adjusted that when the bar (B) is in a central position the zero line of the scale to be ruled will be normal or perpendicular to the reference lines (L), (L). During the process of ruling the blank is firmly held by clamps (K), (K). A wide range of adjustment is provided by additional tapped holes, (H), (H), for different positions of the clamps, also, the plate (D) may be secured in different positions on the base, (A), by means of screws (E), (E). In the figure, (O) indicates a partially-ruled blank in position. The engraving mechanism (C) can be adjusted to rule a scale of unusual width by loosening the screws (I), (I), and moving the slotted base (U) backward or forward as may be desired; also, additional sockets, (S), are provided for the purpose of ruling scales with zeros near one end.

If the scale is to be spaced by a micrometer (M), the edge of the bar, (B), is held against a pin (P) in the slide of the micrometer, by a spring (not shown), so that when the screw is rotated the bar will move in the path indicated by dotted lines. For convenience in spacing, two rows of tapped holes (H), (H), in the base (A), afford means of securing the micrometer in any position by the clamps (K), (K).

A much less costly and almost equally accurate method of spacing is obtained by the use of a metal angle (R), on the edges of which are cut ratchet racks of different pitches. With two sets of teeth of 2mm and 5mm pitch, respectively, correct spacing of every scale likely to be needed can be obtained by clamping the rack in the proper position on the base (A). To avoid the slight error caused by spacing a diagonal with a rack of appreciable thickness the perpendiculars of the teeth are rounded slightly. All looseness or backlash is avoided by the use of a beveled knife edge (N), which is kept in mesh with the rack by a stiff flat spring, and which is easily and quickly lifted and set in a new position by the knob (T).

This ruling machine, including the rack but not including the micrometer or the engraving mechanism, was built from materials found in the instrument shop of the Weather Bureau at a cost smaller than the price quoted by manufacturers for a single tangential scale. A scale of either pattern described herein can be ruled in about one hour, of which time the larger part must be devoted to adjusting the ruling machine.

RELATIONS BETWEEN WEATHER AND MENTAL AND PHYSICAL CONDITION OF MAN PRESENTED ON THE BASIS OF STATISTICAL RESEARCH.[1]

By ERNST BREZINA and WILHELM SCHMIDT.

[Translated and reviewed by W. W. REED, Weather Bureau, Atlanta, Ga.]

The behavior of the nervous sytem under different weather conditions is the chief subject of an investigation having for test persons census clerks, school children, and epileptics confined in hospital. Investigation was made for all meteorological elements, using current values and changes in value, also for general conditions such as distribution of pressure. These data were entered on cards daily for one year and opposite were placed comparative values characterizing performance of mental work in office or school and condition or behavior in hospital. The following summary based on these data omits mention of those elements for which there appeared no plain relations.

Relative to the influence of change in air pressure it appeared that a certain relation exists for light mental work only; this probably proceeds best with uniform pressure. Neither the number of epileptic patients affected nor the number of attacks shows any decided dependence on air pressure changes, and it is assumed that opposite results are to be referred to a simultaneously changing condition of some kind. It is stated, however, that there appeared plainly an effect of pressure oscillations with periods of 4 to 10 minutes extending for the most part over 24 hours, unfavorable results accompanying the larger amplitudes. It seems probable that these rapid oscillations have essential significance in foehn sickness. Only the marked negative pressure departures proved bad for normal persons, while negative departures generally were found so for epileptics.

In the consideration of the thermal factor there was evident striking difference between the effect upon clerical force and that upon persons affected with epilepsy, which is summarized thus: light mental work is not well done at the time of high temperature or of marked temperature departure, especially in the case of a duration of two days; while epileptics appear sensitive to cold.

For vapor pressure relations were found but little decided; there is to be noted, however, the generally favorable conditions for office force and also for epileptics existing with the normally high vapor pressure of summer. Maximum values of this element are, to be sure, unfavorable. Much more decided results were obtained for relative humidity, and this element appears to have independent significance like that of air pressure and temperature. In winter the best clerical work was done during high humidities (observations taken in the open), but this was due, of course, to their modification to mean values by the heating of offices. Increase in the number of epileptic attacks with high humidity was very plainly shown in winter and was noticeable in summer. Low humidity was found to have bad effect.

Contrary to the prevalent idea, a manifestation of influence by ozone was hardly to be recognized; and at most only a slight effect was to be ascribed to the wind, any influence other than mechanical is presumed explained by other simultaneous conditions.

The relation between meteorological elements that is founded on their connection with position of high and low pressure areas differed so greatly that it could not be accepted as very serviceable. In general, however, the weather prevailing with fall region at the point of observation and with region of rising pressure to the west manifested itself as most unfavorable for office force and pupils, while just the opposite was the case with epileptics.

From the results obtained, the authors believe that this method has proven well adapted and may be especially useful in disclosing the actually effective causes because of the opposite behavior of healthy and sick persons.

The review and discussion of related literature is interesting, especially so since weather effects are given

[1] *Sitzb. Akad. Wiss.*, Wien. mathem.-naturw. Klasse, Band 123, Abt. 3. Oht.-Diz. 1914.

not only for mental and nervous condition but also for physical condition.

Numerous observations by physicians and others show that weather change due to approach of a barometric minimum manifests itself in different symptoms in not a few persons, these usually coinciding with the fall of the barometer and disappearing with the entrance of foul weather. One group of symptoms includes excitement, enervation, lower mental power, dizziness, increase in pulse rate (Frankenhäuser). There is increased discomfort to those persons afflicted with rheumatism and neuralgia. Apoplectic strokes are more frequent with falling than with rising pressure (Berger), and such is the case with death from senile debility, post-mortem examination showing marked dilation in the heart (Radestock). In the months with most frequent and most marked barometric oscillations the number of deaths with mentally diseased persons increases, and there is sudden aggravation in the condition of such persons with rapid fall in atmospheric pressure (Krykiakievitz). Lomer and Kalley find increase in epileptic attacks with pressure oscillations, both explaining the reaction as due to the imperfect adaptibility of the brain of the epileptic to the stimulation caused by rapid change in pressure.

Miller shows sensitiveness because of old wounds and amputations, and Farkas finds among his patients, disabled soldiers, those whose condition changes from very best to very worst with change of northerly wind to sirocco; he asserts also that suffering from rheumatism and gout makes manifest the latent disposition to "weather feeling." Heim reports on "nerve irritating" winds in different regions, noting that in Egypt the dry, dust-laden winds of June bring many patients to the insane asylums at Cairo and greatly excite those already under treatment.

Changes in health may be explained by the difference in air supply, whether there is inflow to a minimum of pressure, vitiated ground air, or outflow from a maximum of pressure, pure air from upper levels (Frankenhäuser).

In physical and mental tests made by Pederson and Lehmann it was found that better results accompany increased light intensity, that there is a most favorable temperature (not the same for all persons) above which there is lessened power, and that there are pressure relations in autumn and winter, poorer execution accompanying falling pressure.

Trabert instituted an investigation at Innsbruck, where the foehn is decided, and found all days termed bad when a barometric depression dominated conditions or was approaching, while all days were termed good when the pressure was high or rising. In view of this he could well say: "As with the weather so also with one's state of health, the distribution of pressure possesses influence in the highest degree."

THE NEBULIZER—A DEVICE FOR ARTIFICIALLY PRODUCING MIST.

By DONOVAN MCCLURE.

[Excerpts from an article, "Laying dust with fog," in the *Scientific American Monthly*, New York, May, 1921, pp. 419-420.]

Dr. L. V. Nicolai, a specialist in diseases of the ear, nose, and throat, and also professor in the University of Pavia, Italy, has recently conducted a number of experiments in the production of artificial fog to overcome the dust conditions in textile factories and other workrooms where tuberculosis thrives as a result of the fine dust particles held in suspension. He calls his process "nebulization."

The nebulized fog produced by Dr. Nicolai's apparatus consists of liquid particles of from 1 to 5 microns in diameter; it spreads in any atmosphere, sharing in the eddies produced in the air either by variations of temperature or by the sweeping movement produced by the arrangement of the apparatus. It flows along the walls, rising and falling and homogenizing the atmosphere, and it takes several hours to settle. These fog particles carry electric charges of equal size which tend to repel each other and thus prevent coalescence, which is a very important point as regards its persistence. Furthermore, it may be made the medium for bearing healing agents, such as balsam, saline salts, etc., which it will distribute in a very homogeneous manner.

Disinfection tests made by the inventor prove that all pathogenic germs not only in the atmosphere, but in fabrics and furs, books and papers, etc., can be completely sterilized in 5 to 12 hours, even where there are several thicknesses of cloth or paper.

A definite degree of humidity is required in workrooms where the fibers of cotton or linen are spun or woven. With this nebulizer it is claimed that the atmosphere may be made sufficiently humid to prevent fraying of the fibers while at the same time leaving it perfectly respirable.—*H. L.*

ATMOSPHERIC PRESSURE AND MINE GASES.[1]

In 1917, from April to November, an engineer of the U. S. Bureau of Mines made a record of the appearance of an unusual gas in a number of the precious metal mines near Eureka, Utah. The occurrence of the gas was associated invariably with a fall of barometric pressure. The gas appeared a few hours after the barometer began to fall and endured until the barometer began to rise. Mr. G. E. McElroy has just now completed an investigation covering a similar period in which many more gas analyses and barometer readings were made.

His conclusion is that the gas, which is extremely heavy (a mixture of carbon dioxide and nitrogen) and will extinguish a light within an inch of the same level repeatedly, is contained in a reservoir in a fractured stratum of rock, and escapes into the mine workings with a falling or low barometer, except during the minor or more rapid falls, which would not allow the gas to escape through the fissures before the rise in the barometer occurs. The ventilating fans serve to work the gas out of the tunnels. It has been the practice to send the hoisting skip into the mine, carrying a carbide lamp, to test for gas before sending any workmen in.

Mr. Benj. F. Tibby, a retired mine operator, has told me that for many years while operating a deep mine at Butte, Mont., he regulated the speed of his ventilating fans by the barometer which he kept at the top of the shaft. He claimed that he secured a greater production per man by increasing the amount of air pumped in to the men when the barometer was low.—*J. Cecil Alter.*

[1] *Cf.* Colliery explosions and barometric pressure. MO. WEATHER REV., 1907, 35: 413.

COMPUTING THE COTTON CROP FROM WEATHER RECORDS AND GINNING REPORTS.

By JOSEPH BURTON KINCER, Meteorologist.

[Weather Bureau, Washington, D. C., May 4, 1921.]

SYNOPSIS.

The harvest of the cotton crop usually begins in extreme southern Texas about July 1. By the middle of August picking is in progress throughout the southern portion of the Gulf Coast States and during the first decade of September this work extends to the more northern districts. Owing to the slow and tedious process of picking, however, harvest is extended over a period of several months, even after the plants are all fully matured, and is not usually finished until well into the winter season.

In conformity with an act of Congress, the Bureau of the Census, Department of Commerce, issues during each harvest season 10 preliminary reports of the amount of cotton ginned to specified dates at approximately semimonthly intervals. They are based on data collected by local agents of the Bureau who canvass the ginners. These reports are considered of great value by those interested in cotton production, as they not only place in possession of all concerned reliable information as to the rapidity with which the crop is being harvested, but by reason of affording deductions as to the amount of the final output made possible by a careful comparison of current reports with those of previous years. The earliest official estimate of the amount of cotton produced is made by the Bureau of Crop Estimates, Department of Agriculture, about December 12, of each year.

While the amount of cotton ginned to a specified date or during a given ginning period has some value as a basis for forecasting the final output, the data are often misleading when the weather factor, which so largely influences the progress of harvest, is ignored.

The rapidity of harvest varies greatly from year to year, depending principally on the earliness or lateness of the crop and the weather conditions prevailing during the harvest season. The relative amounts ginned during the earlier ginning periods in different seasons depends principally on the earliness or lateness of maturity, but later in the season the rapidity of harvest is determined by the prevailing weather conditions.

The relation between the amount of cotton ginned during November and the prevailing weather of that month has been mathematically determined as a basis for forecasting the final output.

By November 1 the cotton crop has practically matured but, on the average, 37 per cent of it remains to be ginned on that date. Fifty-seven per cent of that remaining unginned on November 1 is ginned during the month of November, on the average. These latter percentages vary greatly from year to year, depending on whether November happens to be favorable or unfavorable for picking and ginning. These variations have a very close relation to the number of rainy and cloudy days during the month, which affords a basis for computing the percentages for future years when the relation is mathematically determined. This has been done for the entire cotton belt and the results are given in the accompanying tables.

The closeness of relation between the average number of rainy and cloudy days in the cotton belt and the percentage of the cotton remaining unginned on November 1 that was ginned during November, is shown by the correlation coefficient of -0.91 ± 0.03 (Table 6). This is among the highest coefficients on record where meteorological data are involved.

Ginning data for 15 years, 1905–1919, are available [1] and computations have been made for this period on the basis as outlined, with excellent results. The final computations are shown in Table 8, from which it will be noted that the average error in the computed totals for the 15-year period was only 1.5 per cent, with an error as great as 2 per cent in only 5 of the 15 years, while it was less than one-half of 1 per cent in one-third of the years. By the application of the constants of the equation, shown in Table 7, to the November weather data in future years a reliable computation of the cotton crop can be made in less than 5 minutes after the amount of cotton ginned to December 1 is reported by the Bureau of the Census. The final report of yield is not made by that Bureau until the latter part of March, or later.

The progress of harvest, or ginning, of the cotton crop each year is shown by reports issued by the Bureau of the Census, Department of Commerce. These are issued on September 1, September 25, October 18, November 1, November 14, December 1, December 13, January 1, January 16, March 21, and later an annual report showing the total production. In the MONTHLY WEATHER REVIEW for January, 1917, 45: 6–10, the writer gave the results of a preliminary study of the relation between the weather conditions prevailing and the amount of cotton ginned during certain of these ginning periods. This showed that the variations in the amount ginned from year to year during the earlier periods of the harvest season depended, principally, on the earliness or lateness of the crop, and that this, in turn, depended largely on the temperature conditions during the early season of plant growth, mainly during May and June. In addition, it was shown that later in the harvest season the current weather conditions were closely related to the relative amounts ginned from year to year during a given period.

Several additional years of record are now available which substantiate the former conclusions in this respect. With these at hand, a more extensive study has been made of the effect of weather on the cotton harvest, with application of the weather data to the entire cotton belt; the results are given briefly herewith.

Owing to the fact that the double ginning period from November 1 to December 1 is the only one that gives ginning data for an integral calendar month early enough to be of interest from the standpoint of a crop forecast, that period has been selected for this study. Meteorological data are compiled on a monthly basis and, consequently, the selection of any other period would involve a recomputation of data for the entire cotton belt, necessitating a large amount of clerical labor.

The frequency of rainfall and the amount of cloudy weather are the most important meteorological conditions affecting picking. Owing to the nature of the open cotton and the method of handling after gathering, the progress of picking necessarily is greatly affected by the occurrence of rain and by cloudy weather which prevents the staple from drying out so that picking can be accomplished. It is not surprising, therefore, that we find a closer relation between the number of rainy and cloudy days and the amount of cotton harvested than apparently exists between the actual amount of rainfall and the cotton harvested. Light rain with cloudy weather causes delay as serious as heavy rains for the same period.

A correlation has been made between the average number of rainy and of cloudy days during November for each year, and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November. That is, for the purpose of making a forecast of the entire crop, the amount of cotton remaining to be ginned on November 1 is treated as though it were the total crop. When this amount is estimated, it becomes necessary only to add the amount ginned prior to November 1, a known quantity, for completing the computation for the entire crop. The 15-year period from 1905 to 1919, inclusive, was used in this study, the former year being the first for which ginning reports are available. In all cases the cotton data are expressed in values representing the nearest 1,000 running bales, as reported by the Bureau of the Census.

The basis on which the calculations are made is as follows: The average annual cotton production for the 15-year period, 1905–1919, was, in round numbers,

[1] Final data for 1920 had not been published when this article was completed.

12,340,000 running bales. The average number of bales ginned prior to November 1 was 7,788,000 bales, or 63 per cent of the total crop. At this time, November 1, the cotton crop has practically matured, but owing to the slow process of picking, harvest continues for several months later. The average amount remaining unginned on November 1 was 4,553,000 bales, 57 per cent of which was ginned during November, on the average. This latter percentage varied greatly from year to year, depending on whether November was favorable or unfavorable for picking and ginning. The variations show a very close relation, however, to the number of rainy and cloudy days during the month, which affords a basis for computing these percentages for future years. This relation has been mathematically determined and the resultant constants applied to the November weather for an indication of the proportion (or percentage) of the amount remaining unginned on November 1, that was ginned during that month. With a knowledge of the actual amount ginned during November and its percentage relation to the total remaining unginned on the first of that month (as computed from the November weather records), the quotient of the amount ginned divided by the computed percentage gives an indication of the actual total remaining unginned on November 1. By adding to this the amount ginned prior to November 1 the computation for the entire crop is accomplished.

Table 1 shows the average number of rainy days in November for each of the 10 cotton-belt States and for each of the 15 years of record. Table 2 shows the average number of cloudy days in like manner. In each case the averages for the entire State were used, except for Tennessee, where records for selected stations in the western portion of the State (the cotton district) were substituted for the State averages.

In view of the fact that wide variations exist in the amount of cotton harvested in the respective States, the State averages of meteorological data obviously could not logically be combined on an equal basis for the purpose of correlation with the ginning reports. For example, there is ginned, on the average, in Texas about five times as much cotton in November as is ginned in Louisiana during the same month, and to give the meteorological data in the latter State an equal weight with that in the former would clearly be improper. In view of this, ratios have been computed for the several States, based on the average amount of cotton ginned during November in each. These ratios are shown in the lower section of Table 4.

Table 3 shows the averages of the cloudy and rainy days for each State during the period under consideration, while Table 4 shows these averages weighted on the ratio basis. The last column of Table 4 contains the data used for correlation with the November cotton ginning.

Table 5 shows the amount of cotton remaining unginned on November 1 and the amount ginned during that month; also the percentages of the amount remaining unginned on November 1 of the amount ginned during that month. (The November ginning divided by the amount unginned on November 1.)

The usual preliminary procedure of preparing a dot chart to determine whether or not there is a significant relation existing between two variable quantities, and if so, the form that relation assumes, was followed in this case. The result is indicated in Fig. 1. It will be noted from an inspection of this chart that a very good straight line relation exists between these data, as the dots dispose themselves diagonally across the chart with considerable uniformity of arrangement. The relation from year to year for the several years of the series, as shown in figure 2, bears out in a striking manner the indications of the preliminary dot chart.

Table 6 shows a correlation of these data by the familiar least squares method. In this connection the fact that the correlation coefficient here shown, −0.91, with a probable error of only ±0.03, is one of the highest of record where meteorological data are involved, although it is recognized that the number of cases is comparatively small.

The next analytical step is involved in Table 7. The dot chart, figure 1, tells us that the constants of the line of best fit to the data in hand may be determined from the equation $y = a + br$; that is, a straight line equation applies best, with only two unknown quantities. The solution of this equation, for the data given, is shown in Table 7. A detailed explanation of the equations used is contained in Prof. C. F. Marvin's "Elementary

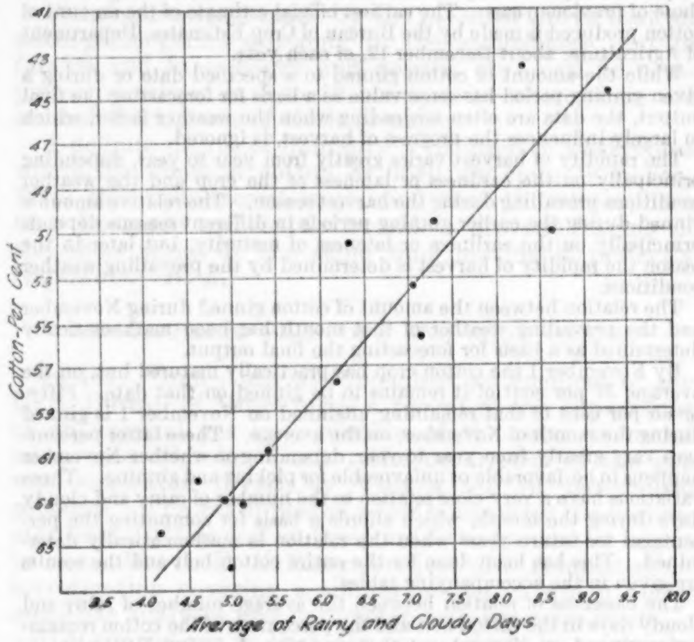


FIG. 1.—Dot chart showing the relation between the number of rainy and cloudy days in November, and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November.

Notes on Least Squares," MONTHLY WEATHER REVIEW, October, 1916, **44**: 551–568, and need not be repeated here. The application of these constants to the weather data given in the column under "r" in Table 7, gives the computed percentages for the several years, shown in column 2, Table 8. The final computations are made in the last-mentioned table. Here, column 1 shows the amount of cotton ginned during November for each of the 15 years, and column 2 the computed percentages that these amounts are of the totals remaining to be ginned on November 1. The values shown in column 1 divided by those shown in column 2 give the computed totals remaining unginned on November 1, as contained in column 3. These latter values, plus the amount ginned prior to November 1 (shown in column 4), give the computations for the entire crop, shown in column 5. Column 6 gives the actual production as reported by the Bureau of the Census several months later, while column 7 shows the percentages of error in the computed forecast for the several years.

It will be noted that the computed crop from year to year is in very close agreement with the actual production, the average error for the 15-year period being only 1.5 per cent. The error is as great as two per cent in only five of the 15 years; it does not exceed 1.5 per cent in nine of the 15 years; and is less than one per cent in seven of the years. *It is less than one-half of one per cent in one-third of the years.* The relation between the computed yields and the actual yields is shown graphically in figure 3.

By the application of the constants of the equations shown in Table 7, to the November weather data and the amount of cotton ginned during that month in future years, a reliable computation can be made early in December of the total cotton crop. This total is not available through the reports of the Bureau of the Census until the latter part of March and occasionally the final report is not issued until considerably later. In addition, it will be seen that by compiling the necessary weather data and computing the constants of the equation for the double ginning period from October 18 to November 14, a similar computation could be made the latter part of November. In this case, however, special arrangements for receiving the necessary weather data, covering this period, before the November monthly summaries are available, would be necessary.

The fact that these computations are made on the basis of, and the results given in, running bales, while the final records of cotton production are expressed by the Department of Agriculture in uniform values of 500-pound bales, is inconsequential. The average weight of running bales, as reported by the Bureau of the Census during the last 10 years, varied from 502 to 508 pounds, with a mean of 505 pounds. It will be seen that by using 505 pounds as a basis, the maximum error in this connection would have been very small during these 10 years, only 3 pounds to the bale. By converting the

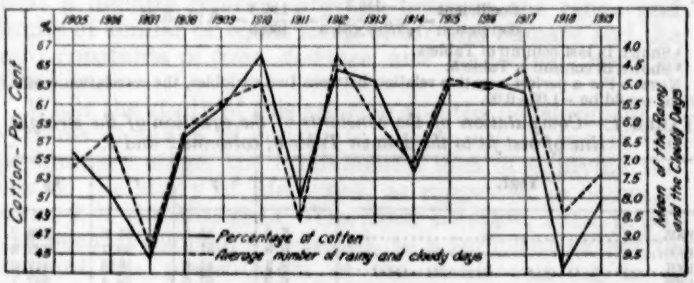


FIG. 2.—Chart showing the relation between the average number of rainy and cloudy days in November and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November for each year from 1905 to 1919, inclusive.

computed running bales to uniform 500-pound bales, on the basis of 505 pounds to the running bale, the average error in the computed totals for the 10-year period from 1910 to 1919 would have been 1.7 per cent, against 1.6 per cent when expressed in running bales as shown in the tables given.

In making deductions as to the significance of the ginning reports issued by the Bureau of the Census as indications of the final output, the advantage of considering the weather factor in connection therewith can not be too strongly emphasized. The following statement appears in the last annual report of the Bureau of the Census:

"The collection of statistics of cotton ginned to specified dates was designed to place in the possession of all concerned reliable data as to the rapidity with which the cotton crop is being harvested and ginned. Statistics compiled by this method have, after a series of years, an incidental but very considerable value by reason of the deductions made possible by a careful comparison of current reports with those of previous years."

The important question in this connection is, how much better indications of the production can be had by applying the weather factor than when the ginning reports alone are considered. The records for the 15-year period, 1905 to 1919, show that on the average 84 per cent of the cotton crop was ginned prior to December 1. If these reports from year to year should furnish a reliable indication of the size of the crop, the relative amounts ginned to December 1 should be in close agreement with the

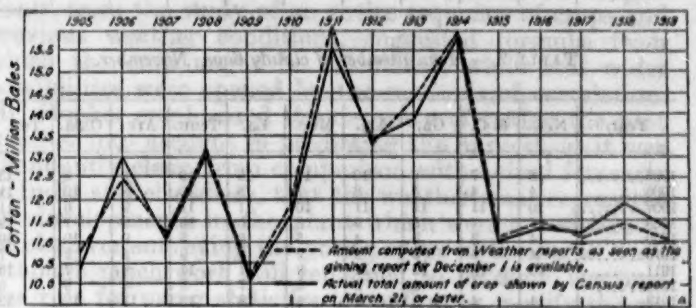


FIG. 3.—Chart showing the total cotton crop, in running bales, as reported by the Bureau of the Census on March 21 or later and the computed yield from weather conditions based on the ginning reports received on or before December 12 each year.

relative production for the respective years, for at this time only 16 per cent of the crop remains to be ginned on the average. By reducing the amounts ginned to December 1 to percentages, based on the average amount ginned to that date, and applying the ratios to the average production for computing the total crop, we find that considerable variations from the actual production frequently appear in the computed output. The errors by this method exceed half a million bales in more than half the years; the maximum error is more than 10 per cent and the average error for the 15-year period is 4.5 per cent, against an average of 1.5 per cent when the weather conditions are taken into account, as computed from the accompanying tables. It may be pointed out also that with the constants of relation between weather and ginning, as shown in Table 7, established, and the weather data for November available, the computation of the final output can be made in less than five minutes after the amount of cotton ginned to December 1 is reported by the Bureau of the Census.

The first, or preliminary, official estimate of the cotton crop is made from year to year by the Bureau of Crop Estimates about December 12. This report is based on the amount of cotton remaining to be ginned as estimated by the correspondents and agents of the Bureau distributed throughout the cotton belt. In connection with this preliminary estimate the following abstract from a note appearing in the *Weekly News Letter* of February 2, 1921, may be of interest:

"An index to the accuracy of the estimates made by the Bureau of Crop Estimates, United States Department of Agriculture, is shown by a comparison of the estimates on cotton yields made by the bureau in December with the annual report of bales ginned issued by the Bureau of the Census the following March. The deviation of the estimates from the census during the period of 20 years, 1900 to 1919, inclusive, was 2.5 per cent and the average underestimate for the 20 years 1½ per cent. In 1915 and 1916 it was less than one-half of 1 per cent—and for the last three years it was about 3 per cent under the final census report."

TABLE 1.—*Mean number of rainy days, November.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	4	3	4	6	6	7	6	5	4	6
1906	3	3	3	5	5	4	8	6	6	6
1907	10	10	11	10	8	8	10	6	4	8
1908	4	3	8	4	5	5	8	8	4	4
1909	4	3	3	3	5	5	5	7	7	5
1910	4	4	5	5	5	5	6	3	1	2
1911	9	8	8	10	8	6	11	7	4	4
1912	5	4	4	4	4	4	4	2	2	2
1913	3	2	3	3	3	3	5	5	7	6
1914	6	6	6	7	6	7	8	4	2	6
1915	5	4	4	5	6	5	9	6	2	3
1916	6	4	5	5	5	3	7	5	4	3
1917	4	4	3	3	4	2	6	4	4	2
1918	5	7	8	7	7	8	9	6	6	7
1919	5	3	5	6	8	7	10	7	6	5

TABLE 2.—*Mean number of cloudy days, November.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	8	7	8	10	11	12	9	9	5	13
1906	4	4	5	8	7	8	10	9	12	11
1907	10	11	11	11	10	11	11	9	6	11
1908	4	4	5	9	8	10	10	9	7	8
1909	4	3	3	4	5	6	8	9	10	10
1910	4	4	6	9	9	9	9	5	3	7
1911	10	13	12	11	9	11	16	8	7	10
1912	4	4	5	5	6	7	8	4	3	6
1913	4	4	5	4	6	8	13	11	12	12
1914	7	7	7	8	10	11	12	9	5	11
1915	5	4	4	6	7	6	10	9	3	4
1916	6	7	6	6	5	4	6	6	5	5
1917	7	5	5	6	7	4	11	9	6	3
1918	7	9	9	9	9	10	11	11	9	12
1919	7	6	9	9	10	9	11	10	8	9

TABLE 3.—*Mean of the cloudy and the rainy days.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	6.0	5.0	6.0	8.0	8.5	9.5	7.5	7.0	4.5	9.5
1906	3.5	3.5	4.0	6.5	6.0	6.0	9.0	7.5	9.0	8.5
1907	10.0	10.5	11.0	10.5	9.0	9.5	10.5	7.5	5.0	9.5
1908	4.0	3.5	6.5	6.5	6.5	7.5	9.0	8.5	5.5	6.0
1909	4.0	3.0	3.0	3.5	5.0	5.5	6.5	8.0	8.5	7.5
1910	4.0	4.0	5.5	7.0	7.0	7.0	7.5	4.0	2.0	4.5
1911	9.5	10.5	10.0	10.5	8.5	8.5	13.5	7.5	5.5	7.0
1912	4.5	4.0	4.5	4.5	5.0	5.5	6.0	3.0	2.5	4.0
1913	3.5	3.0	4.0	3.5	4.5	5.5	9.0	8.0	9.5	9.0
1914	6.5	6.5	6.5	7.5	8.0	9.0	10.0	6.5	3.5	8.5
1915	5.0	4.0	4.0	5.5	6.5	5.5	9.5	7.5	2.5	3.5
1916	6.0	5.5	5.5	5.5	5.0	3.5	6.5	5.5	4.5	4.0
1917	5.5	4.5	4.0	4.5	5.5	3.0	8.5	6.5	5.0	2.5
1918	6.0	8.0	8.5	8.0	8.0	9.0	10.0	8.5	7.5	9.5
1919	6.0	4.5	7.0	7.5	9.0	8.0	10.5	8.5	7.0	7.0

TABLE 4.—*Mean of the cloudy and the rainy days (Table 3) weighted on a scale of 100 in the ratio of the average number of bales of cotton ginned during November in each State.*

Year.	N.C.	S.C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.	Total.	Cotton-belt average.
1905	4.8	5.0	8.4	8.0	10.2	3.8	3.0	7.0	4.0	18.0	72.2	7.2
1906	2.8	3.5	5.2	6.5	7.2	2.4	3.6	7.5	8.1	16.2	63.0	6.3
1907	8.0	10.5	15.4	10.5	10.8	3.8	4.2	7.5	4.5	18.0	93.2	9.3
1908	3.2	3.5	9.1	6.5	7.8	3.0	3.6	8.5	5.0	11.4	61.6	6.2
1909	3.2	3.0	4.2	3.5	6.0	2.2	2.6	8.0	7.6	14.2	54.5	5.4
1910	3.2	4.0	7.7	7.0	8.4	2.8	3.0	4.0	1.8	8.6	50.5	5.0
1911	7.6	10.5	14.0	10.5	10.2	3.4	5.4	7.5	5.0	13.3	87.4	8.7
1912	3.6	4.0	6.3	4.5	6.0	2.2	2.4	3.0	2.2	7.6	41.8	4.2
1913	2.8	3.0	5.6	3.5	5.4	2.2	3.6	8.0	8.6	17.1	59.8	6.0
1914	5.2	6.5	9.1	7.5	9.6	3.6	4.0	6.5	3.2	16.2	71.4	7.1
1915	4.0	4.0	5.6	5.5	7.8	2.2	3.8	7.5	2.2	6.6	49.2	4.9
1916	4.8	5.5	7.7	5.5	6.0	1.4	2.6	5.5	4.0	7.6	50.6	5.1
1917	4.4	4.5	5.6	4.5	6.6	1.2	3.4	6.5	4.5	4.8	46.0	4.6
1918	4.8	8.0	11.9	8.0	9.6	3.6	4.0	8.5	6.8	18.0	83.2	8.3
1919	4.8	4.5	9.8	7.5	10.8	3.2	4.2	8.5	6.3	13.3	72.9	7.3
Average[1]	202	254	355	243	290	104	92	236	223	484	2,492	......
Ratios[2]	8	10	14	10	12	4	4	10	9	19	100	......

[1] November ginning, to nearest 1,000 bales.
[2] By States, based on average November ginning.

TABLE 5.—*Per cent of the cotton remaining unginned on November 1, that was ginned during November.*

Year.	Remaining unginned on November 1.	Ginned during November.	Per cent column 3÷2.
1	2	3	4
1905	4,037	2,232	55.3
1906	6,077	3,122	51.4
1907	4,930	2,214	44.9
1908	4,894	2,817	57.6
1909	3,055	1,859	60.9
1910	4,222	2,794	66.2
1911	5,582	2,846	51.0
1912	4,620	2,986	64.6
1913	5,153	3,258	63.2
1914	6,079	3,246	53.4
1915	3,689	2,325	63.0
1916	2,740	1,728	63.1
1917	4,063	2,529	62.2
1918	4,129	1,794	43.4
1919	5,021	2,539	50.6

NOTE.—The ginning figures are given to the nearest 1,000 bales.

TABLE 6.—*Correlation of mean number of the rainy and the cloudy days in the cotton belt, and the percentage of the cotton remaining unginned on November 1, that was ginned during November.*

Year.	Mean of rainy and cloudy days.			November ginning—Per cent.			Product of column 3 by column 6.
	Average.[1]	Departure.	Square of departure.	Per cent.[2]	Departure.	Square of departure.	
1	2	3	4	5	6	7	8
1905	7.2	+0.8	0.6	55.3	− 1.4	2.0	− 1.1
1906	6.3	−0.1	0.0	51.4	− 5.3	28.1	+ 0.5
1907	9.3	+2.9	8.4	44.9	−11.8	139.2	−34.2
1908	6.2	−0.2	0.0	57.6	+ 0.9	0.8	− 0.2
1909	5.4	−1.0	1.0	60.9	+ 4.2	17.6	− 4.2
1910	5.0	−1.4	2.0	66.2	+ 9.5	90.2	−13.3
1911	8.7	+2.3	5.3	51.0	− 5.7	32.5	−13.1
1912	4.2	−2.2	4.8	64.6	+ 7.9	62.4	−17.5
1913	6.0	−0.4	0.2	63.2	+ 6.5	42.2	− 2.6
1914	7.1	+0.7	0.5	53.4	− 3.3	10.9	− 2.3
1915	4.9	−1.5	2.2	63.0	+ 6.3	39.7	− 9.4
1916	5.1	−1.3	1.7	63.1	+ 6.4	41.0	− 8.3
1917	4.6	−1.8	3.2	62.2	+ 5.5	30.2	− 9.9
1918	8.3	+1.9	3.6	43.4	−13.3	176.9	−25.3
1919	7.3	+0.9	0.8	50.6	− 6.1	37.2	− 5.4
Sums	95.6	....	34.3	850.8	....	750.9	−146.3
Average	6.4	....	....	56.7	....	....	....

$$\text{Coefficient correlation} = \frac{-146.3}{\sqrt{750.9\times34.3}} = \frac{-146.3}{160.5} = -0.91\pm0.03$$

[1] Shown in last column of Table 4.
[2] Shown in column 4, Table 5.
NOTE.—For a perfect negative relation between two variables, the correlation coefficient would be −1.00±0.00.

TABLE 7.—*Computation of the constants of the equation of the straight line of best fit to the data in Table 6, columns 2 and 5.*

Year.	r	y	r^2	ry
1905	7.2	55.3	51 8	398.2
1906	6.3	51.4	39.7	323.8
1907	9.3	44.9	86.5	417.6
1908	6.2	57.6	38.4	357.1
1909	5.4	60.9	29.2	328.9
1910	5.0	66.2	25.0	331.0
1911	8.7	51.0	75.7	443.7
1912	4 2	64.6	17.6	271.3
1913	6.0	63.2	36.0	379.2
1914	7.1	53.4	50.4	379.1
1915	4.9	63.0	24 0	308.7
1916	5.1	63.1	26.0	321.8
1917	4.6	62.2	21.2	286.1
1918	8.3	43.4	68.9	360.2
1919	7.3	50.6	53.3	369.3
Sums	95.6	850.8	643.7	5,276.0

$$y=a+br \quad\text{.....................[1] Equation 1.}$$

$$b=\frac{n(\Sigma ry)-(\Sigma r)(\Sigma y)}{n(\Sigma r^2)-(\Sigma r)^2} \quad\text{..................... Equation 2.}$$

$$a=\frac{\Sigma y-b(\Sigma r)}{n} \quad\text{..................... Equation 3.}$$

Substituting in equation 2 gives:

$$b=\frac{15(5276.0)-(95.6\times850.8)}{15(643.7)-(95.6)^2}=\frac{-2196.5}{516.1}=-4.26 \quad\text{.......... Equation 4.}$$

Substituting in equation 3 gives:

$$a=\frac{850.8-(-4.26\times95.6)}{15}=\frac{1258.1}{15}=83.9 \quad\text{.......... Equation 5.}$$

r, Mean of the average number of rainy and cloudy days in the cotton belt, Table 2, column 6.
y, Percentage of the cotton remaining unginned on November 1 that was ginned during November, Table 6, column 5.

[1] See "Elementary Notes on Least Squares," Charles F. Marvin, MO. WEATHER REVIEW, October, 1916, 44: 551-556.

TABLE 8.—*Computations of total cotton production by the application of the constants of the equation of the straight line of best fit, shown in Table 7, to the weather data and ginning reports for November. Cotton data given to nearest 1,000 running bales, as reported by the Bureau of the Census, Department of Commerce.*

Year.	1	2	3	4	5	6	7
1905	2,232	53.2	4,195	6,458	10,653	10,495	+1.5
1906	3,122	57.1	5,468	6,906	12,374	12,983	−4.7
1907	2,214	44.3	4,998	6,129	11,127	11,058	+0.6
1908	2,817	57.5	4,899	8,192	13,091	13,086	±0.0
1909	1,859	60.9	3,053	7,018	10,071	10,073	±0.0
1910	2,794	62.6	4,463	7,346	11,809	11,568	+2.1
1911	2,846	46.8	6,081	9,971	16,052	15,553	+3.2
1912	2,986	66.0	4,524	8,869	13,393	13,489	−0.7
1913	3,258	58.3	5,588	8,830	14,418	13,983	+3.1
1914	3,246	53.7	6,045	9,827	15,872	15,906	+0.2
1915	2,325	63.0	3,690	7,379	11,069	11,068	±0.0
1916	1,728	62.2	2,778	8,624	11,402	11,364	+0.3
1917	2,529	64.3	3,933	7,185	11,118	11,248	−1.2
1918	1,794	48.5	3,699	7,777	11,474	11,906	−3.6
1919	2,539	52.8	4,809	6,305	11,114	11,326	−1.9
Average							1.5

Column 1.—Amount of cotton ginned during November.
Column 2.—Computed percentage of the cotton remaining to be ginned on November 1, that was ginned during November (computed from equations in Table 7, applied to weather data).
Column 3.—Computed amount remaining unginned on November 1 (column 1 divided by column 2).
Column 4.—Amount ginned prior to November 1.
Column 5.—Computed total crop (column 3, plus column 4).
Column 6.—Total crop, as reported by the Bureau of the Census, Department of Commerce.
Column 7.—Percentage of error in computed amount.
NOTE.—These computations can be made as soon as the ginning report for December 1 is available, while the actual totals are not available through the report of the Census Bureau until the latter part of the following March, or later.

FORECASTING THE CROPS FROM THE WEATHER.[1]

[Abstract of presidential address of R. H. Hooker, before Royal Meteorological Society.][2]

Mr. Hooker remarked that forecasts of the harvest fell into two main groups, viz, those which predicted the recurrence of good and bad crops in cycles, and those which computed the actual amount by which the yield was improved or damaged by the weather during or shortly before the growing period. He outlined the evolution of the methods of ascertaining relationships between the weather at different seasons of the year and the subsequent harvest. Originally writers such as Gilbert and Lawes could only examine the meteorological conditions in years of exceptional abundance or scarcity. A great advance was made when Sir Rawson Rawson and, later, Sir Napier Shaw, from the study of an entire sequence of crops and previous weather conditions, suggested formulæ from which the crop might be calculated, while still wider possibilities were opened by the methods of correlation. Mr. Hooker emphasized the necessity of taking the past weather into account in predicting the harvest, as it was abundantly clear, from comparison with actual forecasts in India and elsewhere, that the weather was responsible for developments in the plant which were not visible to an observer surveying the young crops in the fields; and, although much work still remained to be done, the time was ripe for using statistics to confirm or modify the results of direct observation of the growing plants.

[1] *Quar. Jour. Roy. Met'l. Soc.*, Apr., 1921, 47:75-99.
[2] Reprinted from *Nature* (London), Jan. 27, 1921, p. 714.

BIOCLIMATIC ZONES DETERMINED BY METEOROLOGICAL DATA.[1]

By ANDREW D. HOPKINS.

[U. S. Department of Agriculture, Washington, D. C., Apr., 1921.]

In a comprehensive study of the relation of the Bioclimatic Law to the natural and artificial distribution of terrestrial plants and animals of the world the writer has developed a system of bioclimatic zones on the theory that a definite relation prevails between the range and limits of similar or equal zones of life and climate and the unit constants of *time*, *distance*, and *the thermal mean* of this law.

While the study of this relation and the development of systems of tables of constants, charts, etc., is yet in the preliminary stage, the fundamental idea of applying the law to the study of life zones, as suggested in SUPPLEMENT 9 of the MONTHLY WEATHER REVIEW, 1918, p. 38, has been developed, and tested, to a sufficient extent to warrant the presentation of the result relating to a *thermal mean principle* of forecasting the bioclimatic zones that are represented by the meteorological stations of the world.

The term *Bioclimatic Zone* has been adopted to include the elements of both life and climate that characterize the zonal complex of responses, primarily to the solar factor, and secondarily to those represented by the variable features of the earth's surface.

The classification of zones to meet the requirements of universal application is briefly as follows:

The major zones are the frigid, temperate, and tropical, designated by Roman numerals I, II, and III. These majors are divided into minor frigid, minor temperate, and minor tropical, which are designated by Arabic numerals.

I. The Major Frigid Zone is Arctic, Antarctic, and Alpine, with Minor Frigid 1, 2, 3, and 4 from the poles and from higher to lower altitudes.

II. The Major Temperate Zone is south and north of and below Major Frigid I, with Minor Temperate 1, 2, 3, 4, 5, 6, and 7, south and north of and below Minor Frigid 4.

III. The Major Tropical Zone is south and north of and below Major Temperate II, with Minor Tropical 1, 2, 3, 4, south and north of and below Minor Temperate 7.

This system of designations and classification of the zones is with the idea of adopting a terminology that is applicable to any continental or insular area of both hemispheres, instead of the usual names based on geographical features, political divisions, regions, etc., of one country or continent.

The major zones of this classification are not different from those which have long been recognized, except that their poleward and equatorward limits *do not follow the parallels of latitude even at sea level.*

The minor zones correspond in general to the minor temperate zones proposed by Dr. Merriam for North America, but his Hudsonian and Canadian do not apply to other continents and Austral and Sonoran for North America do not apply in the same way to South America or Africa.

CHARACTERIZATION OF BIOCLIMATIC ZONES.

Each major and minor zone is characterized by some peculiar element or group of elements of life and climate by which it may be recognized anywhere on the face of the earth where it is represented by greater or less land areas.

The index or characterization elements of the minor zones and their subdivisions into sections are many and varied. Some of the principal ones are the thermal

[1] Presented before the American Meteorological Society, Washington, D. C., Apr. 20, 1921.

index, life type and ecological index, the isophane and altitude index including timberline, and the phenological index.

Among these features of characterization the thermal mean is fundamental as a response to the solar factor; therefore, no matter to what extent the physical aspects as to climate, weather, topography, soil, etc., may vary, the normal range of the characterizing temperature, between the poleward and equatorward or lower and upper altitude limits of a given major or minor zone, will, in general, remain the same.

Therefore, it is to temperature that we must look for the most reliable guide to the preliminary interpretation of the distribution and range of the zones, so far as they are represented by the geographical position of permanent meterological stations from which records are available for a sufficient period of years to represent the normal thermal response to the prevailing influences.

The essential basis for the application of the *thermal mean principle* of identifying bioclimatic zones is a table of sea level thermal constants, for the sea level isophanes of the continents of the northern and southern hemispheres, computed from the records at an intercontinental base. After some months of study of the recorded means sea level isotherms, etc., from different parts of the world, a preliminary table was prepared with Parkersburg, W. Va., as the intercontinental base station; the normal annual July and January means for 15½ years as the base data; the thermal unit constant or gradient of 1° F. to each one degree isophane as the unit of computation the principle of modified thermal influence on life activities with higher and lower latitudes and higher altitudes[2] as the correcting element and the numerical designations of bioclimatic zones corresponding in isophanal range with a corresponding range in the thermal mean for each minor zone and its lower, middle and upper section. This table enables us to indicate the zone represented by the geographical position of any meteorological station in the world, by simply comparing its recorded means with the corresponding thermal constants of the table.

The recorded means at over 600 stations given in Bulletin Q of the Weather Bureau were utilized to test the practicability of the thermal method of zonal predictions, with the result that in nearly every case the recorded mean gave the correct zone as represented by the later life zone maps of the Biological Survey. More recently the records of many hundreds of stations, principally in Eurasia have been compared with the table of constants with most encouraging results.

The thermal principle is based on the theory that—

1. The temperature below that favorable for life activities during the coldest month, January, north, and July south of the Tropical zone contributes to the poleward or higher altitude limit of the species which characterize a warmer zone.

2. The temperature above that favorable for the beginning of life activities during the hottest month, July, north, and January, south of the Tropical zone, contributes to the equatorward or lower altitude limit of the species which characterize a colder zone.

In the application of this principle the following rules are to be followed:

1. When the annual July and January means give the same zone and approximately the same section of the zone, it represents what may be termed a normal or a balanced climate as related to zonal characterization, so that either the annual July or January or the average of the July and January means will indicate the zone and position within the zone represented by the station.

2. When there is a more or less wide variation in the zones indicated by the July and January means, as (*a*) the July represents a more poleward or Alpine and the January a more equatorward zone, either the annual, or the average of the July and January means will serve as the best index, or (*b*) when the July represents a more equatorward and the January a more poleward zone, the July mean will be the best index.

Thus, for a region like the western coasts of North America and western Europe where the winters are abnormally warm and the summers abnormally cool, Rule *a* applies, while in north central North America and Eurasia, where the winters are abnormally cold, and the summers abnormally warm, Rule *b* applies, and in eastern North America and Eurasia where the temperature relations are more equally balanced, as related to the zones, Rule 1 applies.

For examples, *under Rule 1*, for Millsboro, Del., on the eastern coast of North America, the annual July or January gives minor zones $-4+5$,[3] and for Tokyo, Japan, on the east coast of Eurasia, on about the same isophane, the annual and July means give minor $\odot 5$ and the January -5, so that any one of the means in both of these examples indicates approximately the correct zonal position.

Under Rule 2a, for Tatoosh Island, Washington, on the west coast of North America, and about the same isophane as Example 1, the annual and the average of July and January means give minor -3, the July minor -1, and the January minor $\odot 6$, and for Florö, Norway, on the western coast of Eurasia, and on about the same isophane, the annual and the average means give minor $-2+3$, while the July mean gives $-1+2$, and the January $+5$. In both of these examples the annual mean indicates the correct zonal position.

Under Rule 2b, for Willow City, N. Dak., in central North America, the July mean gives $-2+3$, the annual $-1+2$, and the January and the average of the July and January means give $\odot 1$, and for Slatoust, Russia, in central Eurasia, the July gives temperate $\odot 2$, the annual temperate $+1$, the January, *frigid* $+\odot 4$ and the average July and January gives temperate $+1$.

In both of these examples the July mean indicates the correct zone.

It must be remembered that the thermal mean is only one of many methods of indentifying the zone represented by a geographical position and therefore is not to take the place of, but to supplement, the other methods. Its value, however, in making preliminary predictions when no other method is available is clearly indicated in the fact that, for a thousand or more stations, the predictions by this method appear to agree closely with the facts and in many cases do agree as close as they can be determined by any method short of a detailed survey.

Therefore, when we learn to recognize and properly interpret this, and the various other guides to the major and minor features of the bioclimatic zones, it will be an easy matter to not only determine the zones represented by a given region and section of the country but what section or minor element of a zone is represented by a certain place on a given farm. Then we will realize all, and far more, than Dr. Merriam and others have claimed for the life zones, as guides to the development of human welfare in food, health and prosperity.

[2] Hopkins, A. D.: Mo. WEATHER REV., Apr., 1920. 48; 214-215.

[3] $-$ equals lower; $+$, upper; $-\odot$, lower middle; $+\odot$, upper middle; and $\odot$, middle sections of a minor zone.

THE CRITICAL PERIOD OF WHEAT AT COLLEGE PARK, MD.[1]

By W. J. SANDO.

[Author's abstract.]

In the fall of 1920 a careful study was initiated for the purpose of ascertaining the relation of climate to the yield of wheat grown on the Maryland Agricultural Experiment Station farm at College Park. Four varieties of wheat were used in making the study. The yield records cover a period of 12 years.

Correlation coefficients for temperature and precipitation for each month of the growing period and for each variety were determined. A significant negative correlation was found between precipitation and yield for March and May. No significant correlation could be found between temperature and yield.

Other factors were also investigated, but further study will be necessary before their actual relation to yield are determined.

DISCUSSION.

In the discussion of Mr. Sando's paper it was stated by C. F. Brooks that a tabulation of wheat yields and corresponding rainfall in different parts of the United States showed that the best yields were obtained with about 30 inches of annual rainfall, and that the yields where the rainfall was over 50 inches were about as poor as in the regions where the rainfall was less than 15 or 10 inches a year. College Park, Md., being in a region with an average rainfall of about 50 inches a year, would thus have better yields when the rainfall was less than the average, while a place in the semiarid West would have better yields when the rainfall was more than the average. Even though, theoretically, plentiful rainfall between the time of heading and time of harvest should be beneficial, the damage done by smuts and rusts in the warm moist weather of eastern Maryland seems to be responsible for the greatly reduced yields when there is much rainfall in this period.

[1] Presented before American Meteorological Society, Apr. 20, 1921.

INDICATOR PRECIPITATION-STATIONS FOR PREDICTING STREAM DISCHARGE.

By H. L. STONER.

[Abstracted by J. Cecil Alter from an office report, dated January, 1921.]

SYNOPSIS.

Three precipitation stations, widely separated and manned by cooperative weather observers, are utilized to predict the flood-time discharge of Bear River, a Utah-Wyoming-Idaho stream whose watershed covers 2,900 square miles. From precipitation data available at the end of January a prediction can be made, according to the author, as to whether the flood period of March–July will be high or low as compared with the average; at the end of February a verification or modification of the January prediction can be made; at the end of March an approximation of the quantity of the run-off in day second-feet may be ventured; and at the end of April a quantity estimate can be given which will no doubt closely approach the actual flood-period run-off. From a developed relation of flood and nonflood period run-off, it is also claimed to be possible to predict in advance the run-off during the nonflood period. Only quantity forecasts are attempted, no effort being made to state the form of run-off curve.—*J. C. A.*

From the importance which Bear Lake, Utah-Idaho storage has in the successful operating of the generating system of the Utah Power and Light Company, comes the desire to successfully predict as far in advance as possible the probable run-off susceptible to storage.[1] On account of the size of the drainage area, about 2,900 square miles, and the inaccessibility of the greater part of it, which includes mountain regions from 8,000 to 10,000 feet in elevation, the ordinary methods of determining probable run-off by intensive snow surveys can not be attempted.

Several years ago studies were begun by the author to determine whether the data obtained by the existing cooperative stations of the United States Weather Bureau could be used in forecasting probable run-off. The belief was entertained that while these stations were situated in the valleys, they still might serve as "indicators" of the precipitation which occurs over the whole area. This has been found to be approximately the case; and is due apparently to the fact that the more important winter storms extend over large areas and precipitation occurs over similar elevations and slopes with considerable uniformity.

The precipitation records from three cooperative stations have been used, namely Border and Evanston, Wyo., and Laketown, Utah. Border is located on the Wyoming-Idaho border about 12 miles northeast of the north end of Bear Lake; Evanston is near the Wyoming-Utah border about 60 miles south-southeast of the south end of Bear Lake; and Laketown is about 2 miles south of the south end of the Lake. These are the only weather stations in this general region having continuous records for many years, the length of the shortest record being about 18 years. Fortunately these stations are located rather far apart, are in desirable locations, and have dependable observers who have served almost continuously at each of the stations.

As the normal precipitation at the three stations is not the same, in order to give equal weight to the three records, the amount in inches for the various periods for each station has been converted into percentages of the average for the 18-year period, and the mean of the three percentages has been used as required in the comparisons.

The run-off records available are from the Dingle gaging station from 1903 to 1915 and from the Harer gaging station since 1913. The annual values appear in Table 1. Both stations are situated above the point of diversion into Bear Lake from Bear River. The quantity of water diverted from the main stream above Harer is partly a matter of river stage, and more water is diverted when the bulk of the run-off occurs in June rather than when it occurs earlier in the season. This statement, it is believed, explains the somewhat erratic plotting of a part of the Dingle points on the comparison diagrams.

On figure 2 four comparisons of precipitation and run-off are made. These consist of four calendar arrangements of the precipitation, namely, November-January, November-February, November-March, and November-April, each of which is compared with the March-July or flood run-off measured at Dingle and Harer.

[1] Alter, J. Cecil: The weather and daily stream flow for hydroelectric plants. Mo. WEATHER REV., May, 1919, 47: 307-309.

The purpose of the four arrangements is to furnish as early as possible each season as much of a prediction regarding probable run-off as might be ventured. From the relations shown in the comparisons it is possible, as

In figure 3 the August–February or nonflood run-off of Bear River for the years 1903–1919 has been plotted against the previous March–July or flood period run-off. From the relation found to exist between the run-off

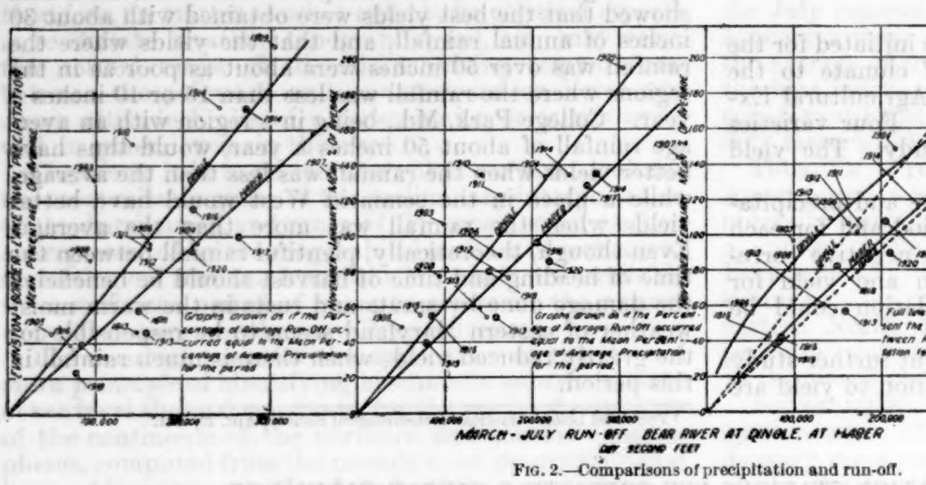


FIG. 2.—Comparisons of precipitation and run-off.

the precipitation records are received from month to month, to venture the following predictions with the positive assurance that the actual run-off performance will bear them out:

At the end of January a prediction as to whether the run-off for the coming flood period will be low, average, or high as compared with other years; at the end of February a verification or modification of the end of January prediction; at the end of March an approximation of the quantity of run-off in day second-feet may be ventured; and at the end of April a quantitative estimate can be given which will no doubt be closely approached by the actual run-off.

This last estimate can be given when the storage period is less than half elapsed. It should be noted that the comparisons provide quantity forecasts only. The rate and time of occurrence are not attempted, as an inspection of the existing run-off records reveals the fact that the form of the flood run-off curves for different years bear little relation to one another.

The straight line graphs on each of the four parts of figure 2 have been drawn as if the percentage of average run-off, March–July, were comparable with the average precipitation, expressed in percentages, for each of the periods shown. This assumption was used for the November–January and the November–February periods simply to show that the tendency of the points was to fall along some such line. The points plotted so scattering for these dates, as a matter of fact, that it was impossible to develop the apparent relation between run-off and precipitation at these times. This assumed relation was continued through the other two periods to show the difference between such assumption and the apparent relation developed by the curves drawn. These curves are apparently the curves of best fit.

Relation between flood and nonflood period run-off.—It being apparent that there is little relation between the precipitation during the summer and the run-off during the corresponding months, the curves shown on Diagram No. 2 have been prepared comparing the run-off for the March–July and the August–February periods. This is essential for the purpose of also determining in advance of its occurrence the available energy of the generating system during the nonflood period.

periods as expressed by the curves, it would seem apparent that the variation of the run-off of one year with another is practically dependent upon the amount of precipitation during the previous winter period, con-

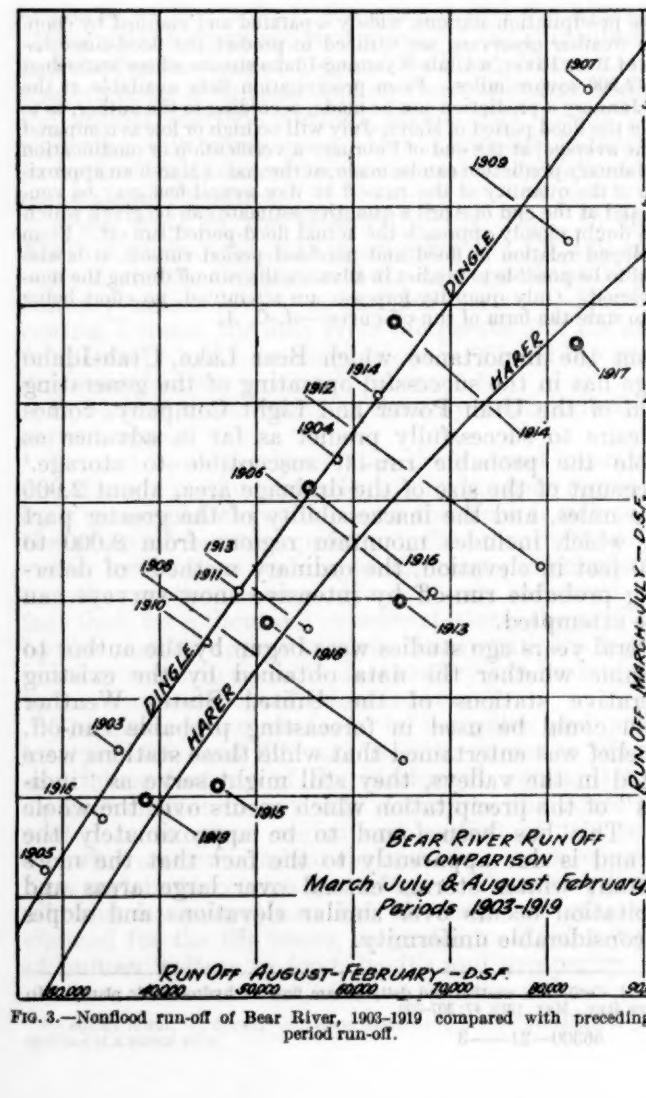


FIG. 3.—Nonflood run-off of Bear River, 1903–1919 compared with preceding flood period run-off.

sidered as November–April; and that the precipitation which occurs outside that winter period, unless abnormal, has relatively little effect in varying the run-off. In other words, it would seem that the winter snows afford the main supply from which the entire year's run-off occurs. Table No. 2 (not reproduced) gives the data shown on Diagram No. 2.

The purpose as stated above for attempting to show the relation expressed by the curves on the diagrams is to permit estimating probable water supply as far in advance as possible. During the period August–February the flow of Bear River is relatively steady and not subject to great range in stage. Hydrographs show much less variation in form during this nonflood period than occur during the flood period. Such being the case, it should be possible to fairly accurately estimate in advance the monthly run-off during the nonflood period by using the form shown by the hydrographs of previous years, being guided as to total quantity by the relation shown in the diagrams.

NOTES, ABSTRACTS, AND REVIEWS.

RESIGNATION OF DR. C. F. BROOKS.

Charles F. Brooks, Meteorologist, United States Weather Bureau and Editor of the MONTHLY WEATHER REVIEW, resigned on June 30, 1921, to accept a newly created associate professorship in meteorology and climatology at Clark University, Worcester, Mass. He writes as follows concerning his new work:

Dr. Wallace W. Atwood, the new president of Clark University, is developing a graduate school of geography. He fittingly recognizes that one of the first requisites in any well-rounded system of instruction in geography is a study of climates, for the atmospheric conditions control to a large extent both the agricultural products and the living habits of man. President Atwood also appreciates that climatology can not be taught adequately without the physical aspects of meteorology. Thus, beginning in the Summer School of 1921, elementary and advanced courses and opportunities for research in both meteorology and climatology are offered. The titles of those to be given in the winter semester are: Meteorology, The Passing Weather, Climatology, Climates of the World, Climatic Environments of the White Race. A fairly complete weather-observing station is being established, primarily for purposes of instruction.

The plan of Clark University includes research as well as teaching. For example, each member of the staff of the School of Geography is expected to spend several months every two years in travel. The results of each expedition are to be published within a year after the return.

The United States Weather Bureau has been most helpful in various ways, especially in providing publications for the university library.

This addition to the all-too-few institutions offering graduate instruction in Meteorology and Climatology is welcomed by the Weather Bureau as providing another source from which its scientific personnel can be recruited.—*A. J. H.*

THE AURORA OF MAY 14-15, 1921.

A brief summary of this brilliant and noteworthy aurora will be presented in the next issue (June) of the REVIEW. Sufficient data were not available in time to include the account in this REVIEW.—*A. J. H.*

FATHER FROC, S. J., HONORED BY FRANCE.

From *Nature*, London (May 5, 1921, p. 308), we learn that the French Government has awarded the Cross of the Legion of Honor to Father Froc, S. J., who for more than a quarter of century has been connected with the meteorological work at Zi-ka-wei Observatory. It was at the Jesuit observatory in Manila that Father Faura in 1879 for the first time predicted the existence, duration, and course of a typhoon in the Far East, and the work at both Manila and Zi-ka-wei has been of the greatest importance to those who sail the China seas. Zi-ka-wei, which stands about 4 miles from the international settlement of Shanghai, derives its name from a distinguished Chinese who was converted to the Christian faith by Matthew Ricci 300 years ago, and whose grave lies close to the observatory. Besides the observatory the Jesuit mission has here a fine cathedral, a college, an orphanage, a convent, and a natural history museum. The work of Father Froc and of his colleagues, Fathers Chevalier and Gauthier, has the support of the community at Shanghai, and the observatory at Zi-ka-wei and those at Zose and Liu-ka-pong connected with it are an object lesson to the Chinese Government.

ORIGIN OF THE SOUTHWEST MONSOON.[1]

By G. C. SIMPSON.

[Reprinted from *Nature*, London, Mar. 31, 1921, p. 154.]

It has generally been held that the southwest monsoon owes its origin to the great difference of temperature which exists during the summer months between the heated land surface of India and the surrounding oceans, the general idea being that the warm air over the land rises, and damp air from the sea flows into India to take its place, thus resulting in the strong southwest winds, the rainfall itself being due to the cooling of the air as it rises over India.

This theory has to face the difficulties that the temperature over India is much higher in May, before the monsoon sets in, than it is during the monsoon itself; that the temperature is higher in years of bad monsoon than in years of good monsoon; and that the part of India which has the highest temperature and the lowest pressure, and where ascending currents should be the greatest, is a region of practically no rainfall throughout the monsoon.

The true explanation of the southwest monsoon can be obtained only by taking a wide view of the weather conditions over large parts of the earth's surface during the summer months in the Northern Hemisphere. It is then seen that the southwest winds are not due to the temperature in India, but are a relatively small part of a general circulation of the atmosphere caused by a region of high pressure over the South Indian Ocean and a region

[1] Abstract of a paper entitled "The Southwest Monsoon," read to the Royal Meteorological Society on Wednesday, March 16

of low pressure which extends over the whole of Central Asia. Air passes northward from the region of high pressure as the southwest trade winds so far as the equator, where it gets caught up in the circulation around the low pressure over Asia. On account of the particular arrangement of sea and land, combined with deflection of wind currents due to the earth's rotation, this air travels for 4,000 miles over the sea before it reaches India, where it arrives in a very warm and exceedingly humid condition. This air, however, would probably sweep right across India to its goal in central Asia without producing much rainfall if it were not for the unique distribution of mountains around India. From the north of the Mokran coast, right around India, following the line of Afghanistan, the Himalayas, and the mountains of Burma, there extends an unbroken wall of mountains, nowhere lower than 5,000 feet, standing directly athwart the air currents. The mountains catch the air, which is being driven by a pressure distribution extending from the Southern Indian Ocean to the center of Asia, in a kind of trap, out of which there is no escape except by ascension. The damp, humid air, which begins to rain as soon as it rises 500 feet, is forced to rise between 10,000 feet and 20,000 feet, and, in consequence, large masses of water are precipitated over the greater part of the Indian area.

STORM WARNINGS IN INDIA.

The Meteorological Department of the Government of India has issued its report on the administration in 1919–20. Observations in connection with the upper air have been developed on behalf of the aviators who are from time to time crossing India. Storm warnings for stations in the Bay of Bengal and in the Arabian Sea are said to have been carried out successfully. It is, however, admitted that the warning of the storm which caused much damage to life and property in eastern Bengal on the night of September 24, 1919, was inadequate. Inland stations were not communicated with until early evening, and were then informed that a "slight to moderate storm" was expected. Special arrangements have been made to avoid the repetition of a similar mishap. The storm, which was tracked from September 22–25, developed rapidly as it approached, and crossed the Bengal coast as a cyclone about noon on September 24. It reached Dacca at about 2.30 a. m. on September 25, and finally broke up on that day in the Assam hills. At the center the deficiency of pressure was about $1\frac{1}{4}$ inches, and the calm area at least 15 miles in diameter. The total loss of life is estimated at 3,500. The value of property destroyed was probably greater than in any storm in Bengal for the last 200 years, but the destruction of human life was probably greater in the Bakarganj cyclone of 1876. An additional terror was caused by a vivid red glow appearing in the sky during the period of the lull. Details are given of the several storms which occurred during the year. Flood warnings are issued and the results are said to be very satisfactory. Rainfall data were received for publication from nearly 3,000 stations for the year.—*Nature (London), April 28, 1921, pages 279, 280.*

OCEAN SURFACE-CURRENTS INDICATED BY DRIFT-BOTTLES AND OTHER OBJECTS.[1]

During the summer of 1919 the Biological Board of Canada set out 330 drift bottles in the Bay of Fundy. Sixteen of these have been picked up on the shores of the Gulf of Maine. Each bottle contained a Canadian postcard on which was printed besides the address of the Biological station, the offer of a reward to the finder who wrote the time and place of finding, and posted the card. Two sizes of bottles were used—2-oz. and 8-oz.; to the latter a galvanized-iron drag was attached to hang at a depth of 3 fathoms, the object of the drag being to minimize the direct effect of the wind. Of the 55 bottles with drags, three were picked up on the Cape Cod peninsula, and three on the Maine coast. Of the 275 bottles without drags, eight were found on Cape Cod and two on the Maine coast. Seven of the bottles (of both sizes) which reached Cape Cod were found after an elapse of between 73 and 80 days. The direct distance between the Bay of Fundy and Cape Cod is 300 nautical miles. This gives an average daily drift of about 4 nautical miles.

The drift of these bottles indicates a surface movement of the water from the Bay of Fundy through the northwestern part of the Gulf of Maine, striking Cape Cod.

On August 29, 1919, drift bottles were set out off the coast of New Brunswick, one of them reaching the Azores on August 8, 1920. From the position in which this bottle was found it is believed that it approached the Azores from the north or northwest. Another bottle, dropped only a mile from the first one and at about the same time, was carried to the Cape Cod coast. It is presumed that the first bottle approached Cape Cod, but being a little farther east was eventually caught by the Gulf Stream and carried to the Azores as just related.

Still a third was put out at the same time about 6 miles northeast of that which went to the Azores. It was picked up on one of the northwestern islands of the Orkney group, on January 21, 1921.

According to the Toronto *Daily Star*, November 1, 1920, a sealed bottle cast into the ocean near Newfoundland in September, 1919, reached Nieuport, Belgium, in August, 1920.

A striking case of drift cited by Mr. Mavor was that of the derelict schooner, *Fannie E. Wolston*, which was adrift for two and a half years and was observed over 30 times. On December 15, 1891, she was seen in lat. 36° N. and long. 74° W. (northeast of Cape Hatteras), and four times afterward on her way across the Atlantic, until she reached lat. 35° N. and long. 39° W. on June 13, 1892, having covered in six months four-fifths of the course between the American coast and the Azores. After reaching the Azores she circled the Sargasso Sea and returned to the American coast by a southern route.

The following account (from the Washington *Times*, August 9, 1920) of the drift of one of the life belts of the ill-fated *Lusitania* furnishes an interesting case of the action of the ocean surface-currents:

PHILADELPHIA, August 7, 1920.—Scientists are greatly interested in the probable route followed by the *Lusitania* life belt recently picked up in the Delaware River off one of the city piers in the center

[1] Abstracted from *Science*, New York, Nov. 5, 1920, pp. 442–443, Feb. 25, 1921, pp. 187–188, and Apr. 22, 1921, p. 389: communications from James W. Mavor.

of Philadelphia. They estimate it traveled from 12,000 to 15,000 miles and required more than five years in its journey.

The *Lusitania* was torpedoed off the Irish coast on May 7, 1915. Hydrographers figure that the belt went through the Irish Sea and around the north of Scotland; down through the North Sea and the English Channel; down the coast of France and Spain and Africa. There the current bore it across the Atlantic. Entering the Gulf Stream, it was carried north. It escaped from this current and drifted to the Delaware capes. Probably the propeller of a steamship caught it up at the capes and brought it up the Delaware. When found afloat it was 100 miles up the river from the capes.

The life belt was covered with barnacles. When these were scraped off the name of the *Lusitania* was found and easily deciphered.

—*H. L.*

THE METEOROLOGY OF THE ANTARCTIC.

By G. C. SIMPSON.

[Excerpted from a review of Vols. I-II of the *British Antarctic Expedition, 1910-1913,* published in *Nature,* (London), Dec. 23, 1920, pp. 526-528.]

It was a fortunate day for meteorology when Capt. Scott invited Dr. Simpson to join his last expedition as meteorologist. The Antarctic has always provided a fascinating field on account of the symmetry of its general circulation combined with remarkable local phenomena; but never before has a meteorologist and physicist of the first rank studied Antarctic meteorology on the spot and presented to the world the digested results of observations planned and executed by himself. * * * The main discussion is divided into nine chapters dealing with temperature, wind, cloud, and precipitation, pressure and its relation to winds and weather, general circulation, the upper air, the height of the Barrier and the plateau, and atmospheric electricity. Each chapter contains not merely a discussion of the results of the observations and a rational explanation of the facts revealed, but also some new contribution (such as, for example, a study of the gustiness of the wind) which was rendered possible only by the new instruments and methods not previously available in Antarctic work.

The annual and diurnal variations of temperature are shown to be, on the whole, due to insolation, but two features present difficulty. There is a diurnal variation of temperature during the months when the sun is completely below the horizon, and the "day" hours are, on the whole, warmer than the "night" hours. No rational explanation is given of this effect. The suggestion that it arises from scattered radiation from the upper layers of the atmosphere which come into the sunshine during the "day" hours is not mentioned, and it appears to be excluded by the fact that the effect is more marked on cloudy than on clear days, and by the further fact that on clear days there are two maxima at about 4 a. m. and 4 p. m., the time of minimum pressure in the semi-diurnal barometer oscillation. The unusual feature in the annual variation is roughly this: On the Barrier the amplitude of the variation is "oceanic" and the phase "continental," while in the Arctic the amplitude is "continental" and the phase "oceanic." The explanation put forward is, roughly, that the continents of Asia and America control the amplitude in the Arctic Ocean, and the Antarctic Ocean controls the amplitude on the Barrier; the argument is well stated, but it is not entirely convincing.

The records from the Dines pressure-tube anemometer, many of which are reproduced, add greatly to the interest of the chapter on wind, and, indeed, to that on temperature, too, by the light they throw on blizzards and other sudden changes. The winds at Cape Evans were found to be about 50 per cent more gusty than the winds at Scilly and Holyhead; but the gustiness decreased as the speed of the wind increased, indicating, according to Dr. Simpson, that the high value was due, not to the exposure, but to the interaction between a warm upper current and a cold surface layer which are coexistent in the Antarctic more frequently than in England.

Pressure waves traveling outwards from the center of the continent are Dr. Simpson's contribution to the explanation of the synoptic charts of the Antarctic. He rejects Lockyer's scheme of traveling cyclones, and pours scorn on the suggestion that the motion of the air in a blizzard is part of a very large cyclonic system. "A depression with its center in 60° S. able to produce a blizzard of 40-60 miles per hour in 78° S. is of course quite inconceivable. Whatever blizzards may be due to, they are certainly not part of the circulation around a cyclone the center of which is more than 1,000 miles away." He appears here to be doing less than justice to Lockyer's scheme, which may represent the broad features of the pressure distribution, even although all the cyclones do not adhere rigidly to the sixtieth parallel of latitude.

The theory of pressure-waves will undoubtedly provoke much discussion; facts are marshalled in an imposing array to support it, and theoretical synoptic charts are produced which are wonderfully similar to the charts based upon actual observations. The pressure waves are apparently not sound waves; they are described as "true pressure waves traversing the upper atmosphere in the same way that water waves travel across the sea"—i. e., they are waves formed at a surface of discontinuity. As the waves appear to be at least 500 miles from crest to trough, there can not be very many of them—probably, in fact, not more than one—in existence at a time, so that the comparison ought to be with one long wave in shallow water (e. g., a tidal wave) rather than with "water waves traveling across the sea"; it appears doubtful if it is possible at the surfaces of discontinuity, which certainly exist in the Antarctic, to get waves 500 miles long traveling at 40 miles per hour, and having pressure amplitudes of 20 millibars at sea level. The horizontal transference of a large mass of air naturally suggests itself as an alternative explanation, but the adjustment of the motion to the pressure gradient presents difficulties.

In his discussion of the general circulation Dr. Simpson arrives at conclusions agreeing in some respects with Hobbs, and in others with Meinardus. Broadly speaking, he makes the whole continent an anticyclonic area surrounded by a broad band of low pressure about latitude 65; but at 10,000 feet the plateau alone is anticyclonic, while a very marked cyclone is centered over the part of the Antarctic which is near sea level. The upper winds deduced from cloud observations and from Erebus's smoke fit in well with the scheme.

The free atmosphere over the Antarctic had never been explored before Dr. Simpson sent up his *ballons-sondes;* the results of this first attempt are remarkably good, although the stratosphere was not reached. Out of 21 ascents, 14 instruments were recovered, of which 12 furnished good records; but three of them referred to different times on one day, November 19, 1911. In six cases of summer ascents the temperature decreased steadily upwards at a rate of about 6° C. per kilometer; in four cases of winter ascents temperature rose at the commencement of the ascent, and began to fall only after a height of one or two kilometers had been reached The lowest temperatures recorded in these ascents was −46° C. (−51° F.) at a height of 6,750 m. (22,000 feet)

on Christmas Day, 1911. The lowest temperature recorded on the Barrier was −60° C. (−76° F.) on July 6, and this is the lowest temperature recorded anywhere in the Antarctic.

METEOROLOGICAL STATION IN GREENLAND.

In *Nature* for May 26, 1921, it is stated that the Danish Government is to make provision at an early date for the establishment in Greenland of a high-powered radio and meteorological station. This action is in accordance with a recommendation of the International Commission for Weather Telegraphy which met in London last November. Such a station will be of untold value to weather forecasting in Europe and possibly in Canada and the United States also. At present the gap between American and European meteorological observations is so great that American observations can hardly be used for European forecasting; but the establishment of the Greenland station will serve as a bridge to this gap and enable European meteorologists to make definite and systematic use of American weather observations.—*C. L. M.*

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1921.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, June 30, 1921.]

For a description of instruments and exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225.

From Table 1 it is seen that solar radiation intensities averaged slightly above the normal at all the stations. At Santa Fe, maximum noon intensities of 1.60 gr. cal. per min. per sq. cm. measured on the 19th and 25th are very close to the previous high record for May of 1.61.

Table 2 shows a deficiency for the month in the total radiation received from the sun and sky at Washington, close to the normal amount for May at Madison, and a slight excess at Lincoln.

Skylight polarization measurements obtained on nine days at Washington give a mean of 56 per cent, and a maximum of 63 per cent on the 9th. Measurements obtained at Madison on 5 days give a mean of 66 per cent, and a maximum of 70 per cent on the 4th. These are slightly above the average values for May at both stations.

TABLE 1.—*Solar radiation intensities during May, 1921.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					Air mass. P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
May 2	6.76	0.75	0.88	1.02	1.20	1.40					6.50
7	6.76				1.16	1.45					6.02
9	6.27			0.82	1.11	1.44	0.80	0.43			4.75
10	7.57	0.63	0.74	0.85	1.04	1.23					7.04
14	13.13					1.35	1.03				8.48
17	4.95	0.66	0.77	0.93	1.13	1.42	1.07	0.86	0.75		5.16
18	8.48	0.53	0.63	0.78	0.98	1.22					9.83
20	9.83		0.51		0.88						7.57
31	13.13			0.85	1.08	1.35	1.03	0.87	0.75		13.13
Means		0.64	0.71	0.88	1.07	1.36	0.98	0.72	(0.75)		
Departures		+0.03	−0.01	+0.06	+0.08	+0.07	−0.01	−0.05	+0.04		

* Extrapolated.

MADISON, WIS.

[Gram-calories per minute per square centimeter of normal surface.]

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					Air mass. P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
May 4	5.16				1.24	1.45					6.76
5	6.27				1.21	1.41					7.29
6	6.50					1.34					7.04
7	6.27				1.21	1.38					6.27
8	7.29			0.91							5.36
Means				(0.91)	1.22	1.40					
Departures				−0.05	+0.11	+0.05					

LINCOLN, NEBR.

May 2	4.75					1.56	1.29	1.14	0.95	0.85	3.99
3	4.57		0.93	1.09	1.21	1.49					6.02
4	4.95		0.79	0.87	1.04						5.36
5	6.02		0.60	0.74	0.96						7.04
6	6.50		0.77								6.76
12	9.83		0.80	0.87	1.21						9.14
13	5.56		0.94	1.12	1.30	1.55					6.02
14	3.99		0.92	1.03							6.02
20	13.13						1.07	0.80			14.10
26	13.61						1.15				10.50
28	11.38		0.87	1.02	1.17	1.36					13.13
Means			0.83	0.98	1.15	1.49	1.17	(0.97)	(0.95)	(0.85)	
Departures			+0.01	+0.02	+0.01	+0.11	+0.10	+0.08	+0.20	+0.14	

SANTA FE, N. MEX.

May 3	4.17		1.13	1.23	1.34	1.47					2.36
5	3.15	1.03	1.14	1.24							1.78
12	3.45		1.06	1.22	1.37						2.62
18	4.37		1.07	1.18	1.27						3.81
19	4.57			1.22	1.40	1.60	1.40	1.22			2.16
20	3.00		1.08								3.15
24	7.04		1.07	1.21	1.40						5.79
25	3.63		1.08	1.22	1.39	1.60	1.34	1.22	1.07		2.49
27	4.57							1.23			3.45
28	3.63		1.07	1.19	1.31						2.36
Means		(1.03)	1.09	1.21	1.35	1.56	(1.37)	1.22	(1.07)		
Departures		+0.02	+0.02	+0.03	+0.05	+0.04	+0.09	+0.01	−0.05		

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 30	189	432	560	−275	−17	+97	−1,290	−5,254	+1 392
May 7	426	493	452	− 51	+29	−35	−1,644	−5,049	+1,146
14	605	464	506	+120	−11	− 4	− 800	−5,124	+1,121
21	422	497	590	− 70	+18	+70	−1,296	−4,995	+1,608
28	567	477	[1] 529	+ 71	−22	− 6	− 801	−5,152	+[2]1,576

[1] For the five days ending June 1. [2] June 1.

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, June 29, 1921.]

In continuation of preceding publications, I give in the following table the results obtained at Montezuma, near Calama, Chile, in April, 1921, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

Readers will have noted that the number of observations reported from Chile in the months of January, February, and March was, relative to the former years, very small, and the same is true, to a less extent, of April. Furthermore, the observations reported are almost exclusively taken by the short method. Owing to the empirical nature of the short method, it is our purpose to confirm the accuracy of these values by frequent simultaneous applications of the longer and fundamental method of observing. The unprecedented cloudiness of the Chile station for the first four months of the year 1921 has been the cause both of the paucity of observations and of the almost complete lack of observations by the fundamental method. This feature of the weather in Chile is but another instance of the extraordinary character of the weather thus far in the year 1921 in many parts of the world.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρ .C.	V. P.	Rel. Hum.	
1921. A. M.	*Cal.*					*Cm.*	*Per ct.*	
Apr. 1	1.952	$M_{1.40}$	S−	0.870	0.679	0.36	18	Cirri over high peaks.
	1.942	$M_{1.40}$						
	1.948	W. M						
2	1.957	$M_{1.22}$	S−	.878	.736	.26	11	Some cirri in north.
5	1.965	$M_{1.46}$	S−	.876	.684	.33	12	
6	1.953	$M_{1.25}$	S−	.874	.725	.23	10	Some cirri in north and east.
P. M. 8	1.946	$M_{1.44}$	S	.865	.614	.29	13	Cirri prevented earlier observations.
	1.954	$M_{1.37}$						
	1.950	W. M						
A. M. 9	1.952	$M_{1.22}$	S−	.867	.648	.34	19	
	1.947	$M_{1.29}$						
	1.950	W. M						
10	1.918	$M_{2.10}$	S−	.859	.456	.55	39	Cirri in north and east.
	1.938	$M_{1.43}$						
	1.931	W. M						
12	1.926	M_{3}	S	.870	.498	.39	31	Cirri in north and west.
	1.917	$M_{2.5}$						
	1.923	M_{2}						
	1.922	W. M						
14	1.955	$M_{1.28}$	S−	.869	.502	.37	19	Cirri prevented earlier observations.
	1.957	$M_{1.25}$						
	1.956	W. M						
15	1.944	$M_{1.29}$	S−	.875	.674	.30	15	Little cirri in west.
	1.951	$M_{1.24}$						
	1.947	W. M						
P. M. 16	1.952	$M_{1.6}$	S−	.878	.661	.29	11	Cirri prevented morning observations.
	1.939	$M_{1.67}$						
	1.946	W. M						
A. M. 17	1.956	$M_{1.72}$	S−	.877	.655	.27	17	Some cirri in north and east.
	1.948	$M_{1.55}$						
	1.952	W. M						
18	1.944	$M_{1.32}$	S−	.877	.706	.25	12	Little cirri low in east.
	1.946	$M_{1.26}$						
	1.945	W. M						
19	1.934	M_{2}	S−	.877	.610	.23	16	
	1.908	$M_{2.35}$						
	1.920	W. M						
P. M. 21	1.921	$M_{2.36}$	S−	.880	.620	.13	62	Cumulus in east, some cirri in north, east, and west.
25	1.946	$M_{1.56}$	S−	.879	.725	.18	77	Cirri scattered about sky.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month of May was near the normal at all of the land stations on the American and European coasts, as well as in the West Indies and the Bermudas, while it was considerably higher than usual at Horta, Azores.

The number of days on which fog was reported was apparently somewhat less than usual over the Grand Banks and western section of the steamer lanes, while it was slightly above the normal east of the 30th meridian and north of the 45th parallel.

In May there is usually a decrease in the number of days with winds of gale force, as compared with April, and the month under discussion was no exception to the rule, as gales were not reported on more than two days in any 5-degree square.

On the 2d there was a LOW central about 200 miles east of Nantucket that moved slowly eastward and on the 7th reached the coast of Ireland. This disturbance reached its greatest development on May 5, as shown on Chart IX, although the storm area of that day was of limited extent, with winds of maximum force of 9, as shown by following storm logs:

American S. S. *Frank A. Morey:*

Gale began on the 1st, wind NNW. Lowest barometer, 29.68 inches at 1 a. m. on the 2d; wind NNW.; position, latitude 36° 06′ N., longitude 72° 50′ W. End on the 2d. Wind NNW. Highest force of wind 9, NNW; steady from NNW.

Dutch S. S. *Nieuw Amsterdam:*

Gale began on the 1st, wind ENE. Lowest barometer, 29.48 inches at 6 a. m. on the 2d, wind ENE.-7; position, latitude 39° 55′ N., longitude 62° 53′ W. End of gale on the 2d, wind ENE. Highest force of wind 9, ENE.; steady from ENE.

Dutch S. S. *Barendrecht:*

Gale began on the 3d, wind SW. Lowest barometer, 29.66 inches at 1 a. m. on the 3d, wind SW., 7; position, latitude 39° 41′ N., longitude 50° 19′ W. End of gale on the 3d. Highest force of wind, 8, SW; shifts SW.-W.

American S. S. *Montana:*

Gale began on the 5th, wind WSW. Lowest barometer, 29.45 inches at 9.54 a. m. on the 5th, wind WSW., 9; position, latitude 45° 46′ N., longitude 33° 42′ W. End of gale on the 6th, wind WNW. Highest force of wind 9, WSW.; shifts WSW.-WNW.

The observer on board the British S. S. *Mauretania* states than on the night of May 5-6 the ship encountered an electric storm at latitude 40° 40′ N., longitude 62° W. At first the winds were light and variable, with vivid lightning and heavy thunder and torrential rain. It finished with hard squalls from the WNW. At 5:50 a. m. on the 6th had an exactly similar storm.

On the 6th and 7th light to moderate winds were generally reported between the 25th meridian and the European coast, although the British S. S. *Tranquebar* encountered a strong northwesterly gale on those days, as shown by the following storm log:

Gale began on the 6th, wind W. Lowest barometer, 29.50 inches at 5 p. m. on the 7th, wind WNW.; position, latitude 48° 40′ N., longitude 22° 30′ W. Highest force of wind 11, WNW.; shifts W.-NW.

Mr. H. Sloman, the observer on the British S. S. *Lapland*, Capt. Bradshaw, reports:

On May 8, G. M. T. 9.25 p. m. or S. A. T. 4:55 p. m. in latitude 40°N.; longitude 64° W., barometer 29.63 inches, dry bulb 64° F., wet bulb 60° F., sea surface temperature 72° F., wind NW. 3, sea slight, with moderate northerly swell, observed two complete waterspouts with others trying to form to northward, distant about 7 or 8 miles. Spouts lasted about 25 minutes and were followed by fresh NNE. wind and rain. The sea was very much disturbed and banked very high at the base of the spouts.

May was evidently an unusually good month for waterspouts, as they were encountered on four other days, as shown by the following extracts from vessel reports.

American S. S. *Glenpool*, Capt. S. Purdy, Second Officer G. Anderson:

At 9:15 a. m., on May 12, while en route from Tampico to New York, three waterspouts were sighted 20 miles S. 15° W. (true) from Diamond Shoals Lightship. They were three points on the port bow, about 1 mile apart, traveling south at a speed of 20 miles an hour and bearing directly for the vessel, so the course was changed to get clear.

American S. S. *F. K. Barstow*, Capt. F. F. Hultgreen, Second Officer J. N. West:

On May 16, in latitude 22° 40′ N., longitude 89° 30′ W., observed a small waterspout about 1 mile to windward, which appeared to be traveling in a south-easterly direction and approaching the ship rapidly. When about 500 feet away it suddenly turned to the southward, clearing the ship's stern by 20 feet. The movement was from right to left with a column of dense vapor extending up to a low-hanging cloud.

American S. S. *San Blas*, Capt. J. C. Scott, Second Officer S. T. Barr:

On May 17, in latitude 23° 40′ N., longitude 82° 30′ W., saw three waterspouts, one large and two small, bearing south 2 miles away.

British S. S. *G. R. Crowe*, Capt. R. J. Green, Second Officer H. Chamberlain:

On May 20, latitude 23° 50′ N., latitude 86° 40′ W., observed eight waterspouts forming and dispersing along the edge of a rain squall in a northeast and northwest direction for a distance of about 6 miles.

From the 8th to the 23d moderate weather prevailed for the most part over the entire ocean, with the Azores High unusually well developed during the greater part of this period. On the 16th westerly gales prevailed over the eastern part of the steamer lanes and on the 23d there was a LOW off the coast of Newfoundland and a limited storm area about 250 miles east of the Virginia Capes.

Storm logs follow:

British S. S. *Cornishman:*

Gale began on the 15th, wind WNW. Lowest barometer 30.04 inches at noon on the 15th, wind WNW., position, latitude 51° 54′ N., longitude 32° 33′ W. End of gale on the 16th, wind W. Highest force of wind 8, WNW.; steady from WNW.

American S. S. *H. M. Flagler:*

Gale began on the 23d, wind WSW. Lowest barometer 29.87 inches at 4 p. m. on the 23d, wind WSW.; position, latitude 37° 18′ N., longitude 69° 28′ W. End of gale on the 23d, wind WSW. Highest force of wind, 8, WSW.; steady from WSW.

There was a display of the aurora borealis on the nights of the 12th, 13th, 14th, and 15th, being especially brilliant on the night of the 14th and early morning of the 15th. It was observed from vessels in all parts of the steamer lanes and along the American and European coasts, and from the British S. S. *Antillian* in the Gulf of Mexico. The observers on board the British S. S. *Bradford City*, while in the North Seas, and the British S. S. *Welshman*, in latitude 40° 30′ N., longitude 49° 49′ W. both noticed a large westerly compass deviation in the early morning of the 15th, that could only be accounted for by this phenomenon.

Mr. L. B. Collins, second officer of the American S. S. *Tuscaloosa City*, Capt. A. W. Pratt: Reports that in approximate latitude 40° 48′ N., longitude 54° 30′ W. at about 6 p. m. S. A. T. on the 14th, on a true course of 269°, the temperature of the water was 48° F., having fallen 11° since 5 p. m.; sea glassy. At 6:15 p. m. crossed into a ruffled surface, and it was observed that two currents existed, one flowing north and the other south. The wake of the vessel was distinctly divided, the smooth surface being carried north and the wake made in the ruffled surface moving south. After being in the ruffled surface for 10 minutes the water temperature had risen to 61° F., and continued to rise until 8 p. m., when it registered 68° F.

On the 24th there was a moderate disturbance over the western portion of the southern steamer lanes as shown on Chart X. Storm log is as follows:

French S. S. *Britannia:*

Gale began on the 23d, wind SW. Lowest barometer 29.70 inches at 11 p. m. on the 23d, wind SW.,8; position, latitude 40° N., longitude 59° 40′ W. End of gale on the 25th, wind NW. Highest force of wind 9; shifts not given.

The observer on the American S. S. *Swiftstar* reports that on the 24th and 25th while between the 82d and 85th meridians near the 24th parallel, encountered a northerly set of current of 15 miles, contrary to chart. Between Sand Key and Alligator Light experienced a strong inshore set, compelling a 7°-change in compass course to overcome same.

The observer on the British S. S. *Corinthic*, reports that on the 25th at latitude 38° N., longitude 67° W. observed abnormally large refraction between 8 a. m. and 4 p. m. which caused sights to vary to the extent of 3° longitude. At 10 a. m. air 61° F., water 62° F., barometer 30.19 inches, wind ENE., 3; cloudy and dry.

On the 28th there was a LOW central near latitude 40° N., longitude 57° W., and moderate southerly gales prevailed over a limited area between the 48th and 51st meridians, with comparatively high barometric readings.

On the 29th and 30th there was a slight disturbance of small extent off the coast of Ireland. Storm log follows:

American S. S. *Editor:*

Gale began on the 29th, wind WNW., 7; lowest barometer 29.60 inches at 4 a. m. on the 30th, wind SW., 7; position, latitude 48° 50′ N., longitude 18° 37′ W. End on the 30th, wind WNW. Highest force of wind 9, WNW.; shifts WNW.-W.-WSW.-NW.

NORTH PACIFIC OCEAN.

By F. G. Tingley.

As determined from observations at the island stations of Dutch Harbor, Honolulu, and Midway Island, pressure over the eastern half of the North Pacific Ocean during May was below normal in middle and low latitudes and above normal in the region bordering the Aleutians. At no time during the month did pressure at the latter two stations equal the normal. At Honolulu the departure was approximately −0.06 inch and at Midway Island −0.14 inch. At Dutch Harbor the departure was +0.12 inch, or, by decades, +0.24, −0.12, and +0.25 inch.

At the beginning of the month anticyclonic systems covered the region between the Hawaiian Islands and the American mainland and that lying between Midway Island and the western Aleutians. Moderate depressions appeared along the American coast, to the westward of the Hawaiian Islands, and southeast of Japan. By the 4th the anticyclones had merged into one system covering the entire eastern half of the ocean with its crest to the southward of the Gulf of Alaska. The depression to the southeast of Japan had moved north-northeastward to the region of the Kuril Islands and developed somewhat. During the several days following this date it moved slowly across the Aleutians and Bering Sea and disappeared over Alaska.

Several vessels, eastward bound, were more or less under the influence of this depression for a period of some 10 days. One of these was the Japanese S. S. *Tokushima Maru*, Capt. Shibutani, Yokohama (April 29) for Vancouver. On the 3d and 4th, when in latitude 46°-47° N., longitude 160°-164° E., this vessel experienced moderate to strong easterly gales.

On the 7th the Japanese S. S. *Arabia Maru*, Capt. K. Komuja, Yokohama (May 1) for Victoria, under the influence of the same depression, had a fresh SE. gale when in latitude 49° 11′ N., longitude 177° 40′ W.

While this disturbance was moving slowly east-northeastward from the Kuril Islands two other depressions were forming, one to the northward of the Hawaiian Islands, the other over Japan. During the period from the 8th to the 15th the former moved very slowly in the direction of the British Columbia coast where it merged with another depression then covering the Rocky Mountain region. The Hawaiian Islands depression reached its greatest development on the 12th and 13th in latitude 45° N., longitude 140° W. On these dates the Japanese S. S. *Tokushima Maru* and *Arabia Maru*, previously referred to, again experienced fresh to strong easterly gales, being now some few hundreds of miles off the American coast.

The second of these two depressions, forming over Japan during the period from the 7th to the 10th, moved slowly in the direction of Alaska, where it was central on the 23d, thence, in varying formation, southeastward over western Canada and the United States, reaching the Atlantic coast on the 29th.

As in the case of the depression of the 4th, a group of ships sailing from ports in the Orient was under the influence of this disturbance for several days, with this difference, however, that whereas in the case of the earlier storm the vessels were in front of the center and experienced head winds, in the later one they were in the rear of the center and had westerly to northerly winds. These varied generally in force from a fresh breeze to a moderate gale.

Only three vessels reported having seen the aurora borealis, so widely observed on the 14th. These were the Dutch S. S. *Bali*, Capt. C. E. Plugge, in approximately latitude 43° N., longitude 135° W., the American S. S. *Hyades*, Capt. E. Pettersen, Observer A. G. Popkin, in latitude 33° 18′ N., longitude 146° 44′ W., and the American S. S. *Manoa*, Capt. E. H. Sandelin, Observer Oliver Bergmann, in latitude 30° 42′ N., longitude 141° 05′ W.

Two ships reported having experienced severe earthquake shocks on the 14th.

One of them was the U. S. S. *Cleveland*, Capt. E. T. Constien, U. S. N., commanding. Observer, Lieut. A. E. Schrader, U.S.N. The *Cleveland* was in the harbor of Manzanillo, Mexico, at the time. At 3:10 p. m., local time, there was a severe shock, of 7 to 8 seconds, east to west motion, undulating. At 3:13 p. m. there was a second shock, 1½ to 2 seconds, fairly light.

The other vessel to experience these shocks was the British S. S. *Spectator*, Capt. W. T. Owen, Observer Wm. Squirrell, Panama for San Pedro. At 3:14 p. m. the *Spectator*, in latitude 18° 50′ N., longitude 104° 42′ W. (off Manzanillo), experienced a very violent shock, shaking the ship from stem to stern. Other shocks were felt

until after 4 p. m., but not so violent. According to Mr. Squirrell, other vessels in the vicinity also reported having felt the shocks.

Notwithstanding the gales referred to, the month as a whole was a quiet one, as would be expected from the advance of the season. This was particularly true of the southern part of the ocean. Mr. N. G. A. Parker, observer on the British S. S. *Nile*, Capt. C. H. Cross, states in his report:

We left Yokohama on May 1 for Honolulu, taking the northern route or Great Circle track, 3,394 miles, and had an exceptionally fine passage, arriving at Honolulu on the morning of the 12th. I should say the month of May was ideal for such route.

Another interesting note is by Mr. G. Clarke, second officer and observer on the British S. S. *Empress of Japan*, Capt. W. Dixon Hopcroft, Yokohama for Vancouver (May 26–June 6). Mr. Clarke states that during the entire voyage the winds were from S. to NE., no westerlies.

WEATHER OF THE MONTH IN THE UNITED STATES.

In general.—The outstanding feature of the month was the anticyclonic control which persisted until the 20th. The anticyclones most influential in this regard had their origin in the Canadian Northwest; associated with their slow movement toward the east-southeast there was a drift of air from higher to lower latitudes and unseasonably cool days during the first half of the month. During the last half higher temperatures prevailed so that the month as a whole in New England, the Lake region, the great interior valleys, the Plains States and the West Gulf States, was one of temperature above the normal. Precipitation was deficient over the same identical regions, also in the north Pacific coast States. It was greater than the average in Atlantic coast districts from Cape Cod to Florida, also in Southern California and generally over the middle and southern plateau regions.

An event of more than passing interest was the severe magnetic storm of the 13th–17th. This storm was accompanied by distrubances of the magnetic and electrical conditions over a large portion of the earth and brilliant auroral displays. A brief summary of the distribution of the auroral display will appear in the June Review.—*A. J. H.*

CYCLONES AND ANTICYCLONES.

By W. P. Day, Observer.

Lows, as a rule, were ill defined and erratic in movement. Offshoots from the subpermanent low pressure area in the Southwest were frequent.

High pressure areas were numerous, but with one or two exceptions avoided interior districts, being more effective in Atlantic coast sections.

Tables showing the number of highs and lows by types follow:

Lows.

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
May, 1921	2.0	1.0	4.0	2.0	1.0	1.0	1.0	....	1.0	13.0
Average number, 1892–1912, inclusive	2.9	1.3	1.2	0.7	1.4	0.7	0.2	0.3	1.0	9.7

Highs.

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
May, 1921	3.0	1.0	5.0	....	2.0	11.0
Average number, 1892–1912, inclusive	1.3	0.5	3.3	0.7	0.9	6.7

THE WEATHER ELEMENTS.

By P. C. Day, Climatologist and Chief of Division.

[Weather Bureau, Washington, D. C., July 1, 1921.]

PRESSURE AND WINDS.

The atmospheric pressure exhibited two distinct types during the month and sharply contrasted weather conditions were the result.

During the first half of the month the pressure was persistently high along the northern border from the Rocky Mountains eastward, the so-called Polar Front extending well into the upper Mississippi Valley during the first few days, and, gradually drifting eastward, extending its influence into the Atlantic coast districts, where it diminished somewhat in force and near the end of the first decade gave signs of dissipating. However, early in the second decade, high pressure again became effective in the Northeastern States and Canadian Maritime Provinces, gradually extending southeast into the Atlantic and becoming central near the Bermudas by the middle of the month. During this period a second high-pressure area had moved into the upper Missouri Valley, and it too passed eastward over about the same course as that first mentioned. Upon reaching the Atlantic coast, however, it slowly settled to the southward, and near the beginning of the last decade of the month had become established over the Southeastern States with a corresponding movement of warm air from the south into the central valleys and thence eastward, where cool, northerly winds had prevailed so continuously during the earlier part of the month.

Low-pressure areas were usually ill-defined and few of them traversed long distances as well-developed storms. The average pressure for the month was highest over the Great Lakes and lowest in the far Southwest. In the districts east of the Rocky Mountains the average pressure was nearly everywhere greater than normal although usually the departures were less than one-tenth inch. Between the Rocky Mountains and Pacific coast, pressure averaged less than normal as a rule; although local areas in the valley of the Colorado River and along the immediate coast had departures slightly above normal.

High winds during the month were usually associated with thunderstorms only and hence were largely local and covered comparatively small areas, although about the first of the month high winds occurred over southern New England and along the middle Atlantic coast, and again about the 4th and 5th over the same districts.

The persistence of high pressure in the Great Lake region caused northerly winds over much of the Ohio Valley, Middle Gulf, and Atlantic Coast States, but between the Mississippi River and Rocky Mountains the wind was mainly from some southerly quadrant, and this was the case also in much of the Plateau region. In the far Northwest and generally along the Pacific coast the winds were from northerly to westerly points.

TEMPERATURE.

In the districts from the Rocky Mountains eastward the temperature during the month exhibited two distinct aspects. The first half of the month, and in a few sections of the middle West a few days beyond, the temperatures were almost continuously lower than the normal for the period, due principally to the persistence of high barometric pressure from the region of the Great Lakes to New England. Temperature changes during this period were usually small, but disagreeably cool, northerly to northeasterly winds prevailed, particularly over the Atlantic coast districts during the first week.

The average temperature for considerable portions of the period ranged from 5° to 10° per day below normal, especially in the Ohio Valley and to the southward during the first decade and in the more central and northern districts during the greater part of the second decade. West of the Rocky Mountains the first decade was mostly cooler than normal but the major portion of the second decade was comparatively warm.

Beginning slightly after the middle of the month most districts east of the Rocky Mountains had a gradual change to warmer weather, and the last two weeks of the month were distinctly warmer than normal in practically all portions of the country from the Rocky Mountains eastward. In the central valleys the average temperatures for this period ranged from 6° to 12° above the normal. Over the far western districts the temperatures during this period were mostly below normal, the first week being particularly cool in the far Southwest.

The main warm periods of the month were during the last decade, particularly about the 20th to 24th, when in the central valleys maximum temperatures were frequently above 100° and in a few cases the highest temperatures ever recorded in May were reported.

The lowest temperatures of the month were mainly during the first few days, particularly in the southern and far western States. In portions of the Lake region and Middle Atlantic States the lowest temperatures did not occur until slightly after the middle of the month.

The month as a whole was warmer than normal over much of the area where the temperatures have continued high during the entire winter and spring period just passed. In fact, over portions of the Middle West the average monthly temperatures have exceeded the corresponding normals for each of the past 9 consecutive months, the average for the entire period exceeding the normal by more than 5° per day.

PRECIPITATION.

During much of the first half of the first decade unsettled, showery weather prevailed in the Middle and North Atlantic States, the upper Ohio and most of the Mississippi Valleys, and in the Pacific Coast States from central California northward during the early part of this period, while during the latter half of the decade rain occurred in the far Southwestern States, including central and southern California where severe drouth had prevailed. The falls were heavy in the lower Mississippi Valley, portions of eastern Texas, and the Middle Atlantic Coast States.

Rainfall was frequent during the second decade from the Mississippi Valley eastward and occurred on two or three days in the northern Great Plains. During the first few days of the decade general rainfall was reported in the Southeast, except over the Florida Peninsula, and shortly after the middle of the month general rains occurred in all southeastern districts, where drouth more or less severe had prevailed, the falls being heavy in much of Florida and in southern Georgia; also rather extensive falls occurred in the Northwest about the close of the decade.

At the beginning of the third decade general rains occurred in the Plateau and south Pacific coast districts, the falls in southern California from the 20th to 23d being unusually heavy, in fact exceeding in some localities any previous records for May. About the middle of this period rainfall was general from the Ohio Valley northward and eastward, and local showers were frequent for several days from the upper Mississippi Valley westward to the Rockies, with some heavy falls in the northern Great Plains area. Rainfall was of a local character during the latter part of the month, and was confined principally to the Northern States.

For the month as a whole, precipitation was above the normal in the central and south Atlantic coast districts, in parts of the upper Mississippi and central Missouri Valleys, and in much of the area west of the Rocky Mountains. In the great central valleys the precipitation was usually considerably less than normal, and in a few small areas the total fall for the month was the least observed in May for more than 50 years.

SNOWFALL.

Snow was confined mostly to the mountain districts of the West and the amounts were small, except in northern Arizona where the fall was unusually heavy for May, though it melted shortly. At a few points in the high mountains of California the falls were likewise heavy, though not unusual for May, and similar conditions prevailed in the high mountains of Colorado.

East of the Rocky Mountains some snow occurred over the northern border States and in the Allegheny Mountain districts.

At Sault Ste. Marie, in the upper Michigan Peninsula, the heaviest snow ever reported in May, 4.5 inches, occurred on the 14th, causing considerable damage to trees.

RELATIVE HUMIDITY.

The distribution of the relative humidity outlined more directly the areas of excess and deficient precipitation than is usually the case. In the central valleys, where precipitation was markedly deficient, relative humidity also was quite deficient, whereas over the Atlantic coast districts the areas of excessive relative humidity coincided mainly with those having more than the normal precipitation. There was likewise an excess of humidity in the districts west of the Rocky Mountains, where precipitation was likewise mostly above average.

LOCAL STORMS.

May 4.—A severe wind and rain storm swept over New York City, Brooklyn, Staten Island, and vicinity about 7:00 p. m. The lighting and power plants were put out of service and car lines abandoned. Several persons were injured by signs blown down. Property damage about $100,000.

May 5.—A severe wind-and-rain storm passed over Los Angeles, Calif., about 8:00 p. m. Houses were unroofed, trees blown down, and much other property damaged. No loss of life.

May 9.—Near Port Arthur, Tex., thunderstorms caused much damage to derricks in the oil fields. Estimated loss $150,000.

May 10.—A tornado crossed Marshall County, Tenn., moving from Carey Springs eastward to near Uniontown, in Bedford County. Much damage occurred at Chapel Hill, where several persons were injured. Estimated damage $50,000.

May 10–12.—Numerous locally-destructive hailstorms occurred in Georgia. Large losses were averted only on account of undeveloped crops.

May 11.—Severe hailstorms in the vicinity of Birmingham, Ala., caused much damage to trees, gardens, and some to roofs and windows. Hailstones from size of nutmegs to baseballs, but small amount of damage, due to the fact that the locality was not a farming section.

May 13.—A tornado swept through Long Branch community, 5 miles south of Lumberton, N. C., and northeasterly to Sampson County, about 2:00 p. m. Three persons were killed and a number injured. Much property loss.

May 13–14.—A severe blizzard swept over Lake Superior during the night, doing considerable damage to shipping.

May 22.—A tornado passed over Waterville, Me. Buildings were blown down and trees uprooted. No one injured.

May 22.—A severe storm at Doughty's Landing, Long Island, Me., caused considerable property damage, and blew four people into the water, one being drowned.

May 22.—A severe wind storm demolished three dwellings and hurled the tower of the American Chemical Company's factory into Penobscot Bay at Searsport, Me.

May 22.—Portland, Me., sudden squalls of wind in afternoon caused much damage throughout city and adjacent sections.

May 22.—A severe windstorm blew down or wrecked several buildings at Worcester, Mass. One man and a girl were slightly injured by flying débris.

May 23.—Three distinct hailstorms occurred in Maryland during the afternoon. The first about 2:30 p. m. moved southward across Washington County in a path about 1 mile wide. Hail varied from the size of a pea to hickory nuts and larger. Estimated damage to crops, $100,000. The accompanying wind uprooted trees and unroofed barns. The second, about 3:30 p. m., a thunderstorm with heavy hail moved southeasterly across Kent, Queen Annes, Caroline, and Dorchester Counties. The path varied from 1 to 6 miles in width. The hailstones were from 1 to 1¾ inches in diameter. Two persons were injured. Property loss about $100,000; the third, about 6:00 p. m. in Garrett County. Hailstones reported as large as hen's eggs. Considerable damage to crops and trees.

May 23.—Norfolk, Va., a thunderstorm during the afternoon and night attended by heavy rain, hail, and wind. Damage by fire and water to buildings struck by lightning estimated at $175,000.

May 26–27.—A cloudburst struck Lynchburg, Va., during the night, causing many thousands of dollars damage to truck farms.

May 26.—A tornado swept a path a quarter of a mile wide between Plymouth and Manly, Iowa. One person killed. Severe wind storms raged through a considerable portion of northeastern Iowa, a number of buildings being demolished southwest of Manchester.

May 26.—A small tornado passed over portions of Topeka, Kans., causing slight damage.

May 26.—Severe wind storm at Wichita, Kans., accompanied by thunderstorm. Damage not given.

May 27.—A tornado cut a swath one-half a mile wide and 5 miles long in southeastern Hillsdale County, Mich., during the afternoon. Houses and outbuildings were wrecked and live stock killed. One person severely injured. Property loss about $300,000.

It is reported that wells from 20 to 30 feet deep were emptied of water by the suction of the tornado; and that water in Twin Lakes was drawn by the suction more than 100 feet into the air and fell in torrents over the adjacent land.

May 29.—Hail did much damage in Haywood County, Tenn., over a strip about one-eighth mile wide and 2 miles long near Brownsville.

AURORA.

A notably brilliant and widely reported aurora was observed on the nights of the 14th–15th, and over the more northern districts appeared first on the night of the 13th. It extended far to the southward, notably at San Juan, P. R., where it was the first observed in the 23 years' history of the Weather Bureau station at that point.

It was also observed on the Pacific coast as far south as San Francisco, where no previous note of such an occurrence appears in the past 50 years' record at that place. Considerable interruption to telegraphic and telephonic communication was experienced in the more northern districts of the United States.

A fuller report of this occurrence will appear in the next issue of the REVIEW.

STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

WASHINGTON FORECAST DISTRICT.

The month was not a notable one for storminess in the Washington Forecast District. The only general and violent storm of the month was that of the 3d to 6th, inclusive, on the Middle Atlantic and southern New England coast. This disturbance interfered greatly with shipping on these coasts and considerable damage was done. This no doubt was minimized very greatly because of the timeliness of the warnings. Special forecasts were issued for aviation. The more important of these was in connection with the National Balloon Race from Birmingham, Ala., on the 21st. Another important aviation forecast was that for the 28th for Zone 2, the Middle Atlantic States, which stated that there was a risk of thundershowers during the afternoon. One of the Army planes, flying from Langley Field, Hampton, Va., to Bolling Field, Washington, D. C., encountered one of these disturbances and the machine was wrecked, killing the pilot and five passengers.

Storm warnings on the Great Lakes.—No storm warnings were issued and no general storms occurred on the Great Lakes during the month. The only disturbance out of the ordinary was that of the 13th and 14th, for which strong winds were forecast. This disturbance

was attended by snow on Lake Superior, but at no point did the wind reach gale force.

Storm warnings on the Atlantic Coast.—Storm warnings were displayed at 9:30 a. m. on the 1st at and between Portsmouth, N. H. and Delaware Breakwater; on the 3d at and between Cape Henry, Va., and Boston, Mass.; on the 23d at and between Eastport, Me., and Sandy Hook, N. J. The disturbance of the 3d to 6th, for which ample and timely warning was given, was the only severe storm of the month at the Atlantic coast. This storm had its origin over the East Gulf States on the 2d and on the morning of the 3d it was central over South Carolina, whence it moved north-northeastward and the morning of the 4th it was central over the lower Chesapeake Bay. During the 4th, 5th and 6th a severe northeaster was general along the coast north of the Virginia Capes to the vicinity of Boston. Storm winds prevailed at all points where warnings had previously been displayed. The maximum velocity reported was 60 miles per hour from the northeast at Block Island, R. I., on the 5th.

Storm warnings on the East Gulf Coast.—No storm warnings were ordered for the East Gulf Coast during the month; none were required.

Frost warnings.—Warnings of frosts or temperatures injurious to vegetation were issued on a number of days for the northern and middle portions of the district. No frosts of consequence occurred in the Southern States.

CHICAGO FORECAST DISTRICT.

The temperature during the first half of the month of May, 1921, averaged below normal generally over the greater portion of the Chicago forecast district, especially in eastern sections, while the latter half was unusually warm, record-breaking maxima being registered at many points in the middle Mississippi and lower Missouri valleys during the closing days of the third decade.

Warnings of frost or freezing temperature were of frequent occurrence during the first half of the month and were issued for various portions of the district on the 1st, 2d, 3d, 4th, 8th, 11th, 12th, 13th, 14th, and 15th. The most pronounced periods of cool weather during which frosts and temperatures near freezing occurred progressively over the district were those from the 1st to the 5th, inclusive, and from the 12th to 16th, inclusive.

Special frost warnings were sent to the cranberry growers of Wisconsin on the 1st, 2d, 3d, 4th, 13th, 15th, 16th, 28th, and 31st. No live stock warnings were issued during the month and the only frost warning during the latter half was issued for Montana on the 27th.—*E. H. Haines.*

NEW ORLEANS FORECAST DISTRICT.

Quiet conditions prevailed except for strong winds occurring locally in a few thunderstorms. No storm warnings were issued or required.

Warning of frost in low places in Arkansas was issued on the 3d and 4th, and frost occurred in the extreme northern portion of that State.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

The weather during the month was dominated largely by a series of low pressure areas from the Plateau region, and cool and wet weather prevailed in the greater part of the district. In eastern Colorado, however, the weather was warm and dry.

Frost or freezing temperature warnings were issued for parts of the District on the 1st, 3d, 7th, 8th, 9th, 10th, 12th, 13th, 17th, and 18th, and were followed generally by frost temperatures or freezing weather in localities. On the 13th, however, the anticipated rise in barometer did not occur in northern New Mexico and temperatures remained well above freezing. No warnings were issued after the 18th, and no damaging weather conditions occurred.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

There was a great deal of unsettled weather in this district during the month, but no very severe storms occurred. Storm warnings were displayed on the 5th along the southern California coast, and small craft warnings were ordered on the 1st at Point Reyes and on the 28th along the entire California coast. All of these warnings were fully verified.

The following unsolicited testimonial, dated Summerland, Calif., May 31, 1921, was received from Mr. W. J. Turrentine, in charge of the work of extracting potash from kelp in southern California:

> I take this occasion to thank you and the members of your organization for the splendid service you have given us during the past four years. Your warnings have been a source of a great deal of comfort, and have been of the greatest service to us in enabling us to take precautions upon the approach of storms. We have gotten by during the four years without any damage from the elements, and the success has been due largely to your kind assistance. Your cooperation is most heartily appreciated.

The potash plant operated a barge in the open sea, and consequently it was more frequently endangered than a stauncher craft would have been under similar weather conditions. The potash works will cease operations on June 30, 1921, and for this reason the special warnings furnished them will no longer be required.

Frost warnings were sent to one or more places on ten occasions, mostly to stations in the Plateau section of this district, and they were generally verified.

The feature of the month, besides the prevalence of many days with unsettled weather, was the phenomenal rains in southern California from the 20th to the 23d. They broke all previous records for the month of May, but they were not heavy enough to cause floods of consequence nor to overcome the deficiency in precipitation for the season, though they materially lessened it. On account of the temperatures being below normal, the run-off of streams in California and Nevada was barely sufficient for irrigation and hydroelectric needs.—*E. A. Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

[Weather Bureau, Washington, D. C., June 30, 1921.]

Atlantic drainage.—Warnings were issued on May 1 for a moderate flood in the lower Connecticut River on the following day, and a stage of 16.8 feet was reached at 7 p. m., May 2. The nonoccurrence of a flood stage at Holyoke, Mass., was doubtless due to the opening of the floodgates at the dam. No damage occurred.

Heavy rains on May 13 and 14 resulted in a moderate flood in the Santee River, beginning on May 14 and continuing until near the end of the month. Stages were from 1.2 to 1.5 feet above flood-stage with the crest from May 18 to 21, inclusive. Warnings were issued on May 14, and about $10,000 worth of cattle and hogs were removed from the grazing swamps. No damage was reported.

East Gulf drainage.—The flood in the lower Tombigbee River continued until May 6, with a crest stage at Demopolis, Ala., on May 1 of 50.8 feet, 11.9 feet above the flood stage. The Pearl River flood did not subside until after May 9, while the West Pearl River was in flood until May 17, having been above the flood stage of 13 feet at Pearl River, La., since April 10, a total period of 38 days.

Mississippi drainage.—The crest of the Illinois River flood of April reached Beardstown, Ill., on May 4, with a stage of 14.6 feet, 2.6 feet above the flood stage, and the river remained above 12 feet until and including May 19. This flood was covered in the report for April, 1921. Moderate floods occurred as forecast, around May 10, in the Grand, Osage, and Meramec Rivers of Missouri, and bank-full stages in the Missouri below Lexington, Mo., and the Mississippi River from below Louisiana, Mo., to Alton, Ill. No damage was done.

The Mississippi River at Arkansas City, Ark., reached a crest of 45.4 feet on May 5 and 6 (flood stage 42 feet), falling below the flood stage on May 13. The damage was nominal. The Yazoo River was still above the flood stage of 25 feet at Yazoo City, Miss., at the end of the month, and the crest stage was 30.8 feet from May 10 to 13, inclusive. Damage in the Tallahatchie and Yazoo basins was quite extensive, about 35,000 acres of crops having been flooded while other losses amounted to about $200,000.

Warnings had been issued from April 26 to 30, inclusive, for the flood in the upper Ouchita River, and at Camden, Ark., the flood stage of 30 feet was passed on April 28, the crest stage of 38.1 feet occurring on May 1, flood stages continuing until May 6. Contrary to the usual procedure at this season of the year, this flood was an exceptional on one account of the rapidity and short duration of the rise and the suddenness with which it ceased. Some slight damage was incurred by farmers who had planted their bottom lands. The Atchafalaya River at Melville, La., was also in moderate flood from May 1 to 21, inclusive.

Warnings of bank-full stages in the lower Kansas River and the Osage River in the vicinity of Ottawa, Kans., on May 10 and 11 were well verified. No material damage was done.

The flood in the lower Black River of Arkansas continued until May 23, and that in the lower White River until May 13.

There were no floods of consequence in the rivers of Texas, and no damage was done.

The rises in the upper Canadian, the Green, Grand, Gunnison, and Colorado Rivers were excellently forecast, especially in the latter river. These floods continued into June and will be discussed at a later date.

The annual rise in the Columbia River and its tributaries began after the middle of the month and continued at the end of the month. These floods were not marked, they also will be discussed at a later date.

Flood stages for month of May, 1921.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	Feet.			Feet.	
Hartford, Conn.	16	2	3	16.8	2
Santee:					
Rimini, S. C.	12	14	27	13.5	18-20
Ferguson, S. C.	12	15	30	13.2	19-21
EAST GULF DRAINAGE.					
Tombigbee:					
Demopolis, Ala.	39	(*)	6	51.8	1
Pearl:					
Jackson, Miss.	20	(*)	9	28.4	1
Columbia, Miss.	18	(*)	9	25.0	1
West Pearl:					
Pearl River, La.	13	(*)	17	15.9	3,4
MISSISSIPPI DRAINAGE.					
Scioto:					
Larue, Ohio.	11	(*)	1	11.5	1
Kentucky:					
Jackson, Ky.	8	6	6	11.5	6
Mississippi:					
Alton, Ill.	21	14	14	21.1	14
Arkansas City, Ark.	42	(*)	13	45.4	5,6
Illinois:					
Peru, Ill.	14	(*)	7	15.0	1
Henry, Ill.	7	(*)	16	9.2	1
Peoria, Ill.	16	(*)	7	16.2	1-5
Beardstown, Ill.	12	(*)	19	14.6	4-6
Pearl, Ill.	12	(*)	7	12.5	5
St. Charles, Mo.	25	13	13	25.1	13
Grand:					
Chilicothe, Mo.	18	13	14	19.2	13,14
Meramec:					
Pacific, Mo.	11	2	4	11.4	4
	11	11	13	14.0	12
Valley Park, Mo.	14	3	3	14.0	3
	14	11	13	18.3	13
St. Francis:					
Marked Tree, Ark.	17	(*)	1	17.0	1
	17	11	16	17.2	12-15
Yazoo:					
Greenwood, Miss.	36	(*)	6	37.1	1
Yazoo City, Miss.	25	(*)	(**)	30.8	3,4,10-13
Tallahatchie:					
Swan Lake, Miss.	25	(*)	17	29.2	1
Ouachita:					
Camden, Ark.	30	(*)	6	38.1	1
Atchafalaya:					
Melville, La.	37	(*)	21	37.9	12-15
Smoky Hill:					
Lindsborg, Kans.	19	10	10	19.6	10
White:					
Newport, Ark.	26	(*)	5	30.9	1
Georgetown, Ark.	22	(*)	14	28.0	3
Clarendon, Ark.	30	5	13	30.8	10
Black:					
Black Rock, Ark.	14	(*)	23	23.0	4-6
Cache:					
Patterson, Ark.	9	(*)	18	9.7	12-15
Sulphur:					
Finley, Tex.	24	(*)	2	25.5	1
Ringo Crossing, Tex.	20	4	6	22.6	4
Cypress:					
Jefferson, Tex.	18	2	3	18.8	2
WEST GULF DRAINAGE.					
Sabine:					
Logansport, La.	25	(*)	14	34.5	1
Bon Weir, Tex.	20	11	18	20.4	12-15
Trinity:					
Liberty, Tex.	25	(*)	4	26.9	1
	25	17	18	25.1	17,18

* Continued from April. ** Continued into June.

Flood stages for month of May, 1921—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
WEST GULF DRAINAGE—continued.					
Colorado:	*Feet.*			*Feet.*	
Topock, Ariz.	14	12	12	14.4	12
	14	22	26	15.1	24
	14	31	(**)	14.0	31
Grand:					
Fruita, Colo.	12	30	(**)	12.6	31
Eagle:					
Eagle, Colo.	5	30	(**)	5.1	31
Gunnison:					
Sapinero, Colo.	16	29	(**)	17.5	31
Delta, Colo.	9	30	(**)	9.3	30
PACIFIC DRAINAGE.					
Columbia:					
Marcus, Wash.	24	22	(**)	28.2	31
Vancouver, Wash.	15	17	(**)	23.7	29, 30
Kootenai:					
Bonners Ferry, Idaho	26	25	29	27.4	28
Pend O'Reille:					
Newport, Wash.	16	27	(**)	18.0	31
Clearwater:					
Kamiah, Idaho	14	18	27	14.7	26
Willamette:					
Portland, Oreg.	15	17	(**)	22.9	29

** Continued into June.

MEAN LAKE LEVELS DURING MAY, 1921.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., June 6, 1921.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during May, 1921:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.12	580.58	573.09	246.68
Above or below—				
Mean stage of April, 1921	+0.43	+0.24	+0.30	+0.30
Mean stage of May, 1920	−0.21	−0.16	+0.80	+1.08
Average stage for May, last 10 years	+0.10	−0.02	+0.39	+0.07
Highest recorded May stage	−0.93	−2.94	−1.33	−2.27
Lowest recorded May stage	+1.30	+1.02	+1.78	+1.72
Average relation of the May level to:				
April level		+0.30	+0.40	+0.30
June level		−0.30	−0.20	−0.20

[1] Lake St. Clair's level: In May, 575.62 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS—MAY, 1921.

By J. WARREN SMITH, Meteorologist.

[Weather Bureau, Washington, June 23, 1921.]

The first half of May was too cool for proper germination and growth of warm-weather crops in most States east of the Rocky Mountains but the more hardy grains and grasses, in general, made satisfactory progress. By the 10th of the month corn planting was in progress in the Missouri Valley as far north as South Dakota, but much replanting was necessary in many southern localities. After the middle of the month warmer weather prevailed and there was a substantial improvement in the growth of corn, although it continued too dry in portions of the Southwest. At the close of the month planting was in progress well to the northern limits of the country, while the crop was well cultivated in the Southern States.

It was much too cool for cotton also during the first two weeks of the month, while heavy rain occurred from the Mississippi Valley westward during the first decade. It was necessary to replant much cotton and the cool weather prevented satisfactory germination. Under more favorable weather conditions, however, there was a material improvement in this crop during the latter half of the month, although its general condition continued poor in many localities. Planting was nearly completed in the more northwestern portions of the belt by the close of the month.

The weather was generally favorable for winter-grain crops and satisfactory development was reported in nearly all portions of the country, although the sudden reaction to warm weather after the middle of the month was somewhat unfavorable for wheat in some interior sections, while the dry weather in western Kansas was harmful. Conditions were mostly favorable for spring wheat and that crop made satisfactory advancement during the month; the stand and color were mostly good at the close of the month.

The weather was more favorable for spring oats than had prevailed during April and the crop showed improvement in most sections, but continued in unsatisfactory condition in some localities, particularly in the southern Great Plains. It was too dry in the far Southwest, and during part of the month in the Southeast for meadows, pastures, and truck, and there was considerable frost damage to fruit from the upper Mississippi Valley eastward about the middle of the month. The drought was relieved in the Southeastern States by good rains on the 12th–16th, but it continued dry in the far Southwest. Rainfall benefited ranges in the central and northern Rocky Mountain districts and stock continued in generally good condition, except in parts of the Southwest.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1921.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	70.7	−0.7	4 stations	98	24†	Bay Minette	37	3	1.98	−1.96	Alaga	5.80	Tuscaloosa	0.09
Arizona	64.6	−0.9	2 stations	110	12†	2 stations	22	7†	0.38	0.00	Ft. Valley	2.37	Many stations	0.00
Arkansas	69.7	+0.7	Texarkana	99	31	Dodd City	29	3	2.25	−2.83	Higden	5.49	Hot Springs	0.00
California	58.2	−3.9	2 stations	107	13†	2 stations	15	2	2.10	+0.88	Mount Wilson	11.04	2 stations	0.00
Colorado	52.9	+1.5	Burlington	99	28	Spicer	6	8	1.41	−0.39	Palisade Lake	5.32	Georgetown	0.08
Florida	73.5	−2.2	Sanford	100	30	Garniers (near)	37	4	5.66	+1.95	Satsuma Heights	11.33	Sand Key	1.05
Georgia	70.1	−1.9	Quitman	101	29	Blue Ridge	34	2	4.11	+0.72	Louisville	7.26	Rome	1.29
Hawaii														
Idaho	53.6	+1.2	Glenns Ferry	97	14	Loon Creek	11	3	2.57	+0.77	Hailey	4.85	Avery	0.70
Illinois	65.5	+2.9	8 stations	96	21†	5 stations	29	16	2.09	−2.11	Urbana	5.26	Casey	0.60
Indiana	64.4	+2.1	Howe	100	23	4 stations	28	16	2.31	−1.81	Princeton	4.48	Wheatfield	0.65
Iowa	63.3	+2.8	Cedar Rapids	99	24	Westbend	25	3	4.23	−0.34	Algona	9.41	Winterset	1.32
Kansas	65.5	+2.4	7 stations	100	28†	Richfield	28	2	2.61	−1.31	Kansas City	7.54	Hutchinson	0.24
Kentucky	65.9	+0.3	2 stations	97	28	Middleboro	32	1	2.45	−1.50	Louisa	5.81	Woodbury	1.12
Louisiana	73.1	−0.8	3 stations	100	31	Kelly (near)	36	4	2.74	−1.54	Logansport	6.90	Simmesport	0.25
Maryland-Delaware	61.3	−1.6	Hancock, Md	93	23	Oakland, Md	27	17	5.29	+1.73	Grantsville, Md	8.69	Dover, Del	2.70
Michigan														
Minnesota	57.1	+2.8	Bearsley	99	19	Grand Rapids	14	1	3.47	+0.12	St. Charles	9.42	Warroad	1.20
Mississippi	71.3	−0.4	5 stations	99	29†	2 stations	36	4†	1.60	−3.00	Natchez	3.74	Pontotoc	T.
Missouri	66.4	+2.0	Caruthersville	102	23	Dean	28	3	3.69	−1.20	Kansas City	7.54	Dean	1.28
Montana	51.5	+0.3	2 stations	88	2†	3 stations	17	1†	1.94	−0.32	Crow Agency	5.86	Libby	T.
Nebraska	60.7	+1.6	2 stations	100	28	Canton	21	1	3.62	+0.01	Cairo	10.53	Hebron	0.66
Nevada	54.7	0.0	Logandale	100	12†	2 stations	17	2†	1.99	+1.12	Lamoille	5.22	Logandale	0.24
New England	56.1	+0.8	4 stations	93	21†	2 stations	24	6†	2.59	−0.76	Turners Falls, Mass.	6.49	Cornwall, Vt	0.57
New Jersey	60.2	−0.2	Woodbine	96	22	Culvers Lake	30	17	4.17	+0.21	New Brunswick	6.44	Indian Mills	2.60
New Mexico	59.3	0.0	Hobbs	98	31	Aragon	10	6	2.05	+0.73	Tucumcari No. 2	8.82	3 stations	0.00
New York	57.7	+1.6	West Point	95	22	2 stations	22	4†	2.27	−1.41	Medford	5.24	Lake Placid Club	0.18
North Carolina	64.1	−2.8	2 stations	95	29	Banners Elk	26	2†	4.48	+0.41	Edenton	10.08	Morganton	1.59
North Dakota	53.8	+1.2	2 stations	90	21	Hansboro	16	3	2.46	−0.09	Epping	5.62	Devils Lake	1.03
Ohio	62.1	+1.3	Bowling Green	96	23	Peebles	28	1	3.20	−0.43	Ottawa	6.50	Vickery	1.26
Oklahoma	70.0	+2.5	Oakwood	100	12	Goodwell	29	2	2.04	−2.84	Reno Junction	4.43	Calvin	0.55
Oregon	53.8	+0.3	The Dalles	96	24	Round Grove	11	2	2.14	−0.02	Fish Lake	5.66	Milton	0.21
Pennsylvania	59.8	−0.6	Stroudsburg	93	22	West Bingham	22	17	3.93	+0.26	Arendtsville	8.17	Erie	0.97
Porto Rico														
South Carolina	68.1	−3.1	3 stations	98	26†	Santuck	36	2	5.30	+1.79	Garnett	9.53	Paris Island	3.00
South Dakota	56.5	+1.4	2 stations	95	22†	2 stations	18	15	3.06	+0.02	Canton	7.77	Redig	0.92
Tennessee	66.8	−0.3	Brownsville	98	29	Rugby	31	1	2.37	−1.78	Crossville	5.01	Nashville	1.15
Texas	73.6	+0.6	3 stations	104	30†	Romero	30	7	1.94	−1.74	Palestine	6.61	5 stations	0.00
Utah	55.2	+0.8	St. George	95	27	Blacks Fork	13	10	1.80	+0.40	Garland	4.50	Emery	0.10
Virginia	61.9	−2.7	Hopewell	95	23	Burkes Garden	24	2	4.61	+0.76	Leeds Manor	8.77	Speers Ferry	1.61
Washington	54.8	+0.3	Wahluke	94	31	Paradise Inn	19	1	1.51	−0.66	Cedar Lake	5.30	2 stations	0.10
West Virginia	61.4	−0.7	Logan	96	23	Marlinton	24	9	4.48	+0.45	Martinsburg	10.67	Grafton	2.12
Wisconsin	58.2	+3.4	2 stations	95	21†	Long Lake	17	16	3.06	−0.93	Eau Claire	7.84	Danbury	0.67
Wyoming	49.9	+1.0	Echeta	87	5	Alta	10	1	2.16	+0.06	Riverton	6.22	Hyattville	0.30

*For description of tables and charts, see this REVIEW, January, 1921, p. 41.

†Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, May, 1921.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							55.4	+ 0.9										75	2.70	− 0.6										5.4		
Eastport	76	67	85	29.92	30.01	+ .05	49.2	+ 2.3	86	22	58	33	11	41	40	45	42	78	1.25	− 2.6	8	6,968	s.	44	nw.	22	12	6	13	5.4	0.0	0.0
Greenville, Me.	1,070	6		28.85	30.01		53.4		84	21	67	28	24	40	38				1.97		10						18	4	9		0.8	0.0
Portland, Me.	103	82	117	29.91	30.03	+ .06	54.6	+ 1.1	93	21	63	36	11	46	30	48	43	67	2.06	− 1.6	7	6,592	s.	59	nw.	22	13	10	8	4.7	0.0	0.0
Concord	288	70	79	29.71	30.02	+ .04	57.2	+ 1.5	92	21	70	31	12	45	43				2.82	− 0.4	6	3,556	se.	25	e.	4	11	15	5	4.7	0.0	0.0
Burlington	404	11	48	29.58	30.02	+ .05	57.5	+ 3.6	88	21	69	34	11	46	35				1.00	− 1.8	9	6,982	n.	36	se.	13	8	14	9	5.3	0.0	0.0
Northfield	876	12	60		30.03	+ .06	53.3	− 0.2	88	21	68	26	11	38	41				0.69	− 2.1	5	5,043	s.	28	ne.	23	5	17	9	5.7	0.0	0.0
Boston	125	115	188	29.88	30.02	+ .04	58.0	+ 1.4	93	21	66	41	1	50	32	52	47	71	3.64	+ 0.1	8	7,446	e.	32	e.	5	10	15	6	5.3	0.0	0.0
Nantucket	12	14	90	29.98	29.99	.00	51.0	− 2.0	76	27	57	36	12	45	25	49	48	90	4.43	+ 1.8	12	13,758	ne.	55	ne.	5	11	4	16	6.3	0.0	0.0
Block Island	26	11	46	29.97	30.00	+ .01	53.4	+ 0.5	72	27	59	42	25	48	21	50	49	88	4.85	+ 1.1	12	14,168	sw.	59	ne.	5	13	5	13	5.5	0.0	0.0
Providence	160	215	251	29.84	30.01	+ .03	57.4	− 1.1	91	22	67	37	12	48	33	50	45	68	2.60	− 0.9	8	9,062	ne.	50	nw.	9	11	10	10	5.4	0.0	0.0
Hartford	159	122	140	29.84	30.01	+ .03	59.8	+ 2.3	90	22	70	35	12	49	33	52	46	66	2.82	− 0.7	9	5,744	ne.	34	ne.	23	11	8	12	5.7	0.0	0.0
New Haven	106	74	153	29.90	30.01	+ .02	58.5	+ 0.9	89	22	68	39	12	49	32	52	47	70	4.08	+ 0.4	13	7,402	ne.	34	ne.	5	13	9	9	4.9	0.0	0.0
Middle Atlantic States.							61.0	− 0.7										73	3.92	+ 0.4										6.0		
Albany	97	102	115	29.90	30.01	+ .03	60.9	+ 2.0	92	22	71	39	17	50	30	53	47	62	1.67	− 1.3	7	5,745	ne.	27	ne.	4	20	9	2	3.0	0.0	0.0
Binghamton	871	10	84	29.08	30.01	+ .03	59.2	+ 2.2	88	22	70	32	17	48	36				3.31	+ 0.2	10	3,888	ne.	30	sw.	28	6	15	10	5.8	0.0	0.0
New York	314	414	454	29.67	30.00	+ .01	60.4	+ 1.1	85	22	69	43	17	52	25	53	47	68	3.45	+ 0.3	11	11,022	s.	54	nw	9	6	13	12	6.3	0.0	0.0
Harrisburg	374	94	104	29.62	30.02	+ .04	61.4	− 0.3	89	22	70	45	17	52	28	51	48	65	3.94	+ 0.3	11	2,695	e.	24	ne.	23	7	13	11	6.1	0.0	0.0
Philadelphia	117	123	190	29.89	30.02	+ .03	62.4	+ 0.2	90	22	71	45	6	54	32	56	52	74	3.42	+ 0.2	11	7,805	sw.	37	ne.	4	7	10	14	6.5	0.0	0.0
Reading	325	81	98	29.66	30.00		61.4		88	22	71	43	17	52	30	54	48	64	3.34	0.0	9	3,957	nw	28	ne.	4	7	7	17	6.6	0.0	0.0
Scranton	805	111	119	29.15	30.01	+ .03	60.1	+ 1.3	87	21	70	38	17	50	33	53	48	67	2.28	− 1.2	11	5,321	ne.	38	ne.	4	6	14	11	6.1	0.0	0.0
Atlantic City	52	37	48	29.94	30.00	+ .02	57.6	+ 0.1	84	23	64	45	2	52	33	54	50	79	3.37	+ 0.4	10	6,566	ne.	31	ne.	4	11	8	12	5.3	0.0	0.0
Cape May	18	13	49	30.00	30.02	+ .03	58.8	− 0.2	85	23	66	44	6	52	34	55	52	83	3.35	+ 0.4	11	6,958	s.	44	e.	4	13	5	13	5.6	0.0	0.0
Sandy Hook	22	10	55	29.98	30.01		59.0		86	22	66	45	5	52	24	54	51	81	4.16		11	11,452	ne.	63	ne.	4	4	15	12	6.4	0.0	0.0
Trenton	190	159	183	29.79	30.00		60.3		88	22	70	42	17	50	32	54	50	73	4.04	+ 0.5	11	8,192	ne.	45	ne.	29	5	13	13	6.3	0.0	0.0
Baltimore	123	100	113	29.87	30.00	+ .01	63.1	− 1.1	90	22	71	45	6	55	32	56	51	69	5.99	+ 2.4	13	5,151	ne.	26	ne.	23	8	9	14	6.1	0.0	0.0
Washington	112	62	85	29.88	30.00	.00	62.3	− 1.9	88	23	72	44	2	53	32	56	51	72	5.82	+ 2.0	13	5,203	nw.	26	nw.	1	9	6	16	6.4	0.0	0.0
Lynchburg	681	153	188	29.26	30.00	.00	63.2	− 2.7	90	23	74	41	17	53	38	57	53	73	6.15	+ 2.2	14	5,367	e.	44	nw.	28	7	12	12	6.0	0.0	0.0
Norfolk	91	170	205	29.89	29.99	+ .01	63.0	− 3.2	88	23	71	47	4	55	31	58	54	79	4.72	+ 0.6	12	8,731	ne.	43	nw.	29	5	10	16	6.9	0.0	0.0
Richmond	144	11	52	29.85	30.00	+ .01	63.0	− 4.3	89	23	72	45	2	54	30	57	54	77	3.89	0.0	17	5,471	nw.	28	sw.	13	7	8	16	6.6	0.0	0.0
Wytheville	2,304	49	56	27.66	30.01	+ .02	59.0	− 2.4	81	23	69	35	2	49	34	53	50	76	3.97	+ 0.1	14	3,977	nw.	28	nw.	25	11	11	9	5.3	0.0	0.0
South Atlantic States.							67.7	− 2.1										75	4.49	+ 0.7										6.1		
Asheville	2,255	70	84	27.70	30.03	+ .04	60.5	− 2.1	85	25	70	38	8	51	32	54	50	76	2.85	− 0.9	15	5,585	nw.	36	n.	25	9	12	10	5.5	0.0	0.0
Charlotte	779	55	62	29.16	30.00	+ .01	66.0	− 2.4	89	23	76	43	1	56	30	59	55	72	4.50	+ 0.6	13	3,544	ne.	21	nw.	29	9	6	16	6.2	0.0	0.0
Hatteras	11	12	50	29.95	29.96	− .05	65.0	− 2.1	80	29	71	49	6	59	18	61	59	85	3.80	− 0.3	11	10,344	ne.	40	se.	3	4	9	18	7.2	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.59	29.99	.00	64.8	− 3.3	90	23	74	44	2	56	27	58	54	72	4.09	− 0.8	14	5,639	ne.	30	nw.	29	1	9	21	7.8	0.0	0.0
Wilmington	78	81	91	29.91	29.99	+ .02	66.8	− 2.3	90	29	75	46	1	59	26	61	58	78	6.87	+ 2.8	16	5,653	w.	28	n.	29	4	12	15	6.7	0.0	0.0
Charleston	48	11	92	29.93	29.98	− .03	70.5	− 1.9	97	29	78	50	4	63	23	64	61	76	5.92	+ 2.4	11	7,603	ne.	33	nw.	12	8	13	10	5.8	0.0	0.0
Columbia, S. C.	351	41	57	29.63	30.00	.00	68.7	− 3.1	93	26	78	46	1	59	32	61	57	72	5.97	+ 2.8	8	4,526	ne.	27	sw.	2	6	12	13	6.1	0.0	0.0
Due West	711	10	55	29.25	30.02		67.3		94	26	78	41	1	57	33				4.04		8	5,673	ne.	42	nw.	11	6	13	12	6.0	0.0	0.0
Greenville, S. C.	1,039	113	122	28.90	29.99		66.0		89	29	75	44	7	57	29	58	54	70	5.61		12	5,659	ne.	49	w.	26	8	14	9	5.6	0.0	0.0
Augusta	180	62	77	29.79	29.98	− .01	70.5	− 1.5	95	26	81	46	4	60	33	63	60	72	4.21	+ 1.0	9	4,224	nw.	25	nw.	2	4	13	14	6.5	0.0	0.0
Savannah	65	150	194	29.92	29.99	− .01	71.2	− 1.3	95	29	80	47	4	63	27	64	61	76	2.70	− 0.3	13	8,050	ne.	39	nw.	2	11	9	11	5.8	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	− .02	72.9	− 1.3	93	29	80	47	4	65	24	65	61	74	4.02	− 0.2	9	8,896	ne.	58	se.	12	17	10	4	4.0	0.0	0.0
Florida Peninsula.							75.9	− 2.1										74	5.42	+ 1.2										5.2		
Key West	22	10	64	29.94	29.96	− .01	78.2	− 0.8	87	31	83	66	8	73	15	70	67	72	1.24	− 2.1	10	8,716	s.e.	28	nw.	4	10	13	8	5.0	0.0	0.0
Miami	25	71	79	29.96	29.99		74.6	− 4.0	88	31	81	50	5	68	27	69	65	73	5.60	− 0.8	10	7,277	e.	30	nw.	30	12	11	8	5.0	0.0	0.0
Sand Key	23	39	72	29.91	29.94	− .03	75.6		84	30	78	67	22	74	10	70	67	74	1.05		8	11,412	e.	35	nw.	4	8	14	9	5.5	0.0	0.0
Tampa	35	79	92	29.95	29.98	− .01	74.8	− 1.6	92	28	83	52	4	66	25	67	63	74	9.41	+ 6.5	9	4,974	sw.	24	e.	14	10	16	5	5.2	0.0	0.0
East Gulf States.							71.1	− 1.2										70	2.43	− 1.1										5.2		
Atlanta	1,174	190	216	28.79	30.01	+ .02	68.4	− 1.1	91	24	78	42	4	59	25	60	55	66	1.75	− 1.3	7	7,804	nw.	56	nw.	11	9	10	12	5.8	0.0	0.0
Macon	370	78	87	29.60	29.99	.00	70.3	− 0.8	95	28	81	45	4	60	31	62	57	66	4.04	+ 1.2	7	4,370	nw.	29	ne.	11	6	12	13	6.0	0.0	0.0
Thomasville	273	49	58	29.69	29.99	.00	72.2	− 1.8	96	28	82	45	4	62	27	63	59	69	4.03	0.0	11	3,658	ne.	19	s.	11	7	10	14	6.2	0.0	0.0
Pensacola	56	149	185	29.94	30.00	+ .01	71.0	− 3.8	94	30	77	44	4	64	56	65	62	76	2.57	− 0.1	10	9,573	n.	39	s.	12	8	13	10	5.5	0.0	0.0
Anniston	741	9	57	29.24	30.03	+ .04	68.4	0.0	92	24	80	39	1	56	35				3.14	0.0	9	3,568	nw.	24	nw.	11	12	14	5	4.4	0.0	0.0
Birmingham	700	11	48	29.27	30.03	+ .05	71.0	− 0.6	94	25	82	44	5	60	28	60	55	64	1.24	− 1.8	4	4,348	nw.	24	s.	11	13	13	5	4.5	0.0	0.0
Mobile	57	125	161	29.94	30.00	+ .01	72.3	− 1.3	96	31	81	44	4	63	28	65	61	75	3.07	− 0.9	10	7,064	sw.	40	n.	11	7	21	3	4.8	0.0	0.0
Montgomery	223	100	112	29.76	30.01	+ .02	71.9	− 1.6	94	29	81	46	4	62	26	63	59	69	1.87	− 2.0	9	4,597	e.	28	e.	15	9	12	10	5.4	0.0	0.0
Corinth	469	6																														
Meridian	375	85	93	29.61	30.00	+ .02	70.4	− 0.7	93	30	81	41	4	60	29	63	58	68	1.56	− 2.4	6	4,020	ne.	26	se.	10	10	18	3	4.5	0.0	0.0
Vicksburg	247	65	73	29.75	30.03	+ .06	72.1	− 0.8	95	31	81	47	4	63	25	66	63	76	1.84	− 2.4	6	4,656	ne.	25	se.	10	12	14	5	4.4	0.0	0.0
New Orleans	53	76	84	29.95	30.00	+ .03	74.3	− 0.2	96	31	82	52	5	66	24	66	62	71	1.61	− 2.3	8	3,325	ne.	22	ne.	30	8	18	5	5.2	0.0	0.0
West Gulf States.							73.0	+ 0.3										69	2.46	− 1.6										4.3		
Shreveport	249	77	93	29.74	30.00	+ .05	73.6	+ 0.4	94	31	84	49	3	64	28	64	59	66	3.66	− 0.5	3	4,535	se.	26	s.	8	21	7	3	3.0	0.0	0.0
Bentonville	1,303	11	44				66.7	+ 0.3	89	28	78	33	3	55					3.75		8						14	13	4		0.0	0.0
Fort Smith	457	79	94	29.51	29.98	+ .05	71.4	+ 1.7	94	31	82	42	3	60	32	62	57	64	1.18	− 3.7	7	5,232	e.	34	sw.	10	9	15	7	5.2	0.0	0.0
Little Rock	357	136	144	29.63	30.00	+ .05	70.9	+ 0.5	95	30	80	43	3	61	28	62	56	64	0.75	− 4.4	4	5,608	s.	32	nw.	2	15	10	6	4.0	0.0	0.0
Brownsville	57	4	26				78.2		95	31	88	61	1	68	25				2.40		2		se.							4.1	0.0	0.0
Corpus Christi	20	69	77	29.94	29.96	+ .06	76.2	− 0.3	86	31	81	61	3	71	17	71	68	80	2.72	− 0.1	7	9,137	se.	40	ne.	1	14	9	8	4.5	0.0	0.0
Dallas	512	109	117	29.44	29.97		74.0		95	31	84	49	3	64	31				2.78		5	6,448	se.	40	ne.	1	12	13	6	4.8	0.0	0.0
Fort Worth	670	106	114	29.24	29.95	+ .04	73.4	+ 0.2	93	12	84	47	3	63	31	63	58	65	1.04	− 3.1	6	7,271	s.	40	nw.	27	14	13	4	4.4	0.0	0.0
Galveston	54	106	114	29.94	30.00	+ .06	74.7	− 0.7	88	31	79	61	3	70	15	68	65	76	2.04	− 1.2	2	7,606	se.	34	s.	9	14	12	5	4.1	0.0	0.0
Groesbeck	461	11	56	29.49	29.97		72.2		92	31	83	49	3	62	33				2.49		6	6,755	se.	36	ne.	1	14	13	4	4.6	0.0	0.0
Houston	138	111	121	29.84	29.98		74.9		93	31	84	53	3	65	28				1.57		6	5,494	se.	30	nw.	9	14	14	3	3.8	0.0	0.0
Palestine	510	64	72	29.46	29.99	+ .06	73.0	+ 0.5	93	31	83	48	3	63	27	64	60	70	6.61	+ 1.7	4	4,778	s.	31	n.	9	11	14	6	4.8	0.0	0.0
Port Arthur	34	58	66	29.95	29.99		74.0		91	31	81	57	4	67	24	68	65	76	2.95		6	6,327	s.	39	e.	15	25	4	2	2.2	0.0	0.0
San Antonio	701	119	132	29.23	29.95	+ .05	75.4	+ 0.6	96	10	86	54	10	65	42	66	61	69	2.01	− 1.0	6	5,842	se.	54	nw.	9	8	15	8	5.2	0.0	0.0
Taylor	582	55	63	29.39	30.00	+ .09	74.3	0.0	92	10	84	51	3	64	37				2.15	− 1.9	4	5,930	se.	52	sw.	11	9	14	8	5.6	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, May, 1921*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with 0.01 inch or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F					°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							65.4	+ 0.6										67	2.46	− 1.2										5.9		
Chattanooga	762	189	213	29.22	30.02	+ .03	68.4	− 0.2	92	24	79	43	3	58	29	59	54	65	4.02	+ 0.4	6	5,045	nw.	39	w.	11	8	18	5	5.4	0.0	0.0
Knoxville	996	102	111	28.97	30.01	+ .02	66.2	− 0.3	91	24	76	42	1	56	32	58	53	68	1.85	− 1.8	11	3,979	ne.	34	sw.	27	7	9	15	6.1	0.0	0.0
Memphis	399	76	97	29.63	30.05	+ .09	70.7	0.0	93	31	79	43	3	62	25	60	54	59	1.27	− 3.1	4	3,428	sw.	40	sw.	10	15	9	7	4.3	0.0	0.0
Nashville	546	168	191	29.45	30.03	+ .05	68.4	− 0.4	91	23	78	41	3	59	30	59	54	63	1.15	− 2.4	7	5,933	nw.	30	nw.	5	11	12	8	5.1	0.0	0.0
Lexington	989	193	230	28.97	30.02	+ .02	64.9	+ 0.6	87	31	74	39	1	56	30				1.60	− 1.9	10	8,978	sw.	40	nw.	25	13	7	11	4.6	0.0	0.0
Louisville	525	219	255	29.45	30.03	+ .05	67.2	+ 0.5	93	23	76	39	3	58	29	59	54	66	2.82	− 0.8	9	8,024	n.	42	n.	5	18	6	7	4.0	0.0	0.0
Evansville	431	139	175	29.56	30.03	+ .06	68.1	+ 1.0	93	24	78	39	3	58	27	59	52	62	1.56	− 1.9	5	7,281	n.	36	n.	25	8	17	6	5.0	0.0	0.0
Indianapolis	822	194	230	29.14	30.02	+ .05	65.3	+ 2.0	91	31	75	38	3	56	29	57	51	64	1.55	− 2.4	9	8,169	n.	36	ne.	6	15	10	6	4.5	0.0	0.0
Royal Center	736	11	55	29.27	30.03	......	62.4	......	92	24	74	32	16	51	31				1.91	......	11	6,857	n.	32	w.	13	12	10	9	5.1	0.0	0.0
Terre Haute	575	96	129	29.38	29.99	......	66.6	......	93	24	77	38	4	56	30	58	52	63	1.97	......	7	6,331	sw.	29	n.	5	9	16	6	5.0	0.0	0.0
Cincinnati	628	11	51	29.35	30.02	+ .03	64.6	+ 1.5	89	23	74	39	1	55	32				2.79	− 0.7	13	4,893	ne.	29	ne.	5	13	10	8	4.3	0.0	0.0
Columbus	824	179	222	29.16	30.03	+ .05	62.9	+ 0.6	88	23	72	38	1	54	28	58	54	76	2.67	− 1.0	12	7,476	n.	48	w.	13	10	14	7	4.8	0.0	0.0
Dayton	899	181	216	29.04	29.98	......	64.0	+ 1.1	89	23	73	39	1	55	28	57	52	68	2.26	− 1.6	11	7,159	ne.	39	ne.	5	16	10	5	3.9	0.0	0.0
Elkins	1,947	59	67	27.99	30.02	+ .02	58.4	− 0.7	84	28	70	33	9	47	40	52	48	74	4.21	+ 0.2	12	3,320	nw.	27	nw.	13	6	11	14	6.5	0.0	0.0
Parkersburg	638	77	84	29.37	30.03	+ .04	64.2	+ 0.9	89	23	74	42	9	54	34	57	52	71	4.19	+ 0.7	13	3,475	nw.	34	nw.	13	10	8	13	5.6	0.0	0.0
Pittsburgh	842	353	410	29.11	30.01	+ .02	62.4	− 0.2	85	28	72	40	2	53	33	55	50	67	2.49	− 0.8	13	7,264	nw.	44	nw.	13	7	9	15	6.0	0.0	0.0
Lower Lake Region.							59.6	+ 2.1										70	2.01	− 1.2										4.9		
Buffalo	767	247	280	29.19	30.02	+ .05	56.8	+ 2.3	83	27	64	38	16	50	29	51	47	72	2.11	− 1.0	8	9,895	sw.	42	sw.	13	10	9	12	5.7	0.0	0.0
Canton	448	10	61	29.53	30.00	......	57.6	+ 1.4	86	21	69	34	19	46	36				1.08	− 1.8	8	7,319	ne.	39	w.	15	16	13	2	3.3	0.0	0.0
Oswego	335	76	91	29.64	30.02	+ .05	55.7	+ 1.0	84	21	63	36	17	49	25	51	46	72	2.58	− 0.3	8	6,388	w.	28	ne.	23	10	13	8	4.7	0.0	0.0
Rochester	523	86	102	29.46	30.03	+ .06	59.2	+ 2.5	88	21	68	36	17	50	32	52	45	63	1.50	− 1.4	7	6,012	w.	27	ne.	4	12	8	11	5.0	0.0	0.0
Syracuse	597	97	113	29.39	30.04	+ .06	58.5	+ 1.2	87	21	68	35	17	50	32				2.27	− 1.1	10	6,981	nw.	33	w.	22	8	14	9	5.3	0.0	0.0
Erie	714	130	166	29.24	30.01	+ .03	59.0	+ 1.8	83	28	66	37	17	52	23	54	50	72	0.97	− 2.5	6	9,185	ne.	50	se.	12	11	11	9	4.9	0.0	0.0
Cleveland	762	190	201	29.20	30.02	+ .04	59.8	+ 1.3	85	21	67	39	17	53	24	54	48	69	1.51	− 1.7	7	8,461	ne.	48	w.	28	12	10	9	5.2	0.0	0.0
Sandusky	629	62	103	29.34	30.02	+ .04	61.8	+ 2.6	88	21	70	40	17	54	26				2.28	− 1.0	9	8,128	n.	34	n.	15	9	14	8	5.3	0.0	0.0
Toledo	628	208	243	29.34	30.02	+ .05	62.5	+ 2.8	90	23	72	38	3	53	32	56	52	71	3.97	+ 0.7	9	9,084	n.	44	sw.	27	14	9	8	4.4	0.0	0.0
Fort Wayne	856	113	124	29.10	30.02	......	63.1	+ 2.9	90	23	93	37	16	53	32	56	51	67	2.54	......	11	6,071	n.	30	sw.	31	10	14	7	5.0	0.0	0.0
Detroit	730	218	245	29.24	30.03	+ .06	61.6	+ 3.7	88	22	71	35	16	52	28	56	53	77	1.85	− 1.4	8	8,328	n.	38	w.	27	13	12	6	4.6	0.0	0.0
Upper Lake Region.							56.1	+ 3.4										70	1.72	− 1.7										5.3		
Alpena	609	13	92	29.38	30.05	+ .08	54.0	+ 4.5	92	21	62	33	15	46	35	49	44	73	2.48	− 0.8	7	8,386	se.	58	nw.	22	10	15	6	5.5	T.	0.0
Escanaba	612	54	60	29.38	30.04	+ .07	52.4	+ 2.4	74	22	60	29	15	45	25	48	43	73	1.99	− 1.4	10	7,319	n.	35	ne.	2	11	12	8	4.9	0.1	0.0
Grand Haven	632	54	89	29.34	30.02	+ .06	58.4	+ 3.6	84	20	67	32	2	49	33	52	47	67	1.25	− 2.1	9	7,733	w.	29	w.	14	13	11	7	4.8	0.0	0.0
Grand Rapids	707	70	87	29.26	30.02	+ .05	62.2	+ 3.2	90	30	73	34	2	52	34	54	48	62	1.23	− 2.1	8	4,150	w.	25	w.	13	9	10	12	5.6	0.0	0.0
Houghton	684	62	99	29.32	30.05	+ .08	52.6	+ 2.9	94	21	63	26	14	42	37				2.01	− 1.3	8	7,773	e.	34	w.	14	7	14	10	5.9	2.1	0.0
Lansing	878	11	62	29.08	30.02	......	60.4	+ 2.5	89	21	72	30	16	49	34	54	49	69	1.33	− 2.2	8	4,342	w.	20	nw.	13	10	10	11	5.5	0.0	0.0
Ludington	637	60	66	29.33	30.03	......	55.2	......	78	27	64	32	1	47	29	51	47	75	1.82	......	6	7,043	n.	25	n.	4	13	9	9	4.8	0.0	0.0
Marquette	734	77	111	29.27	30.08	+ .11	51.6	+ 2.6	94	21	60	28	15	43	31	46	41	69	1.67	− 1.6	13	7,201	w.	36	s.	21	5	12	14	6.2	0.4	0.0
Port Huron	638	70	120	29.33	30.02	+ .05	57.0	+ 3.3	89	22	66	33	16	48	33	53	50	79	1.72	− 1.5	5	8,635	n.	36	sw.	18	11	16	4	4.1	0.0	0.0
Saginaw	641	69	77	29.33	30.03	......	59.6	......	89	21	69	33	16	50	33	53	48	69	2.17	− 2.0	8	6,668	ne.	40	ne.	24	10	11	10	5.5	0.0	0.0
Sault Sainte Marie	614	11	52	29.36	30.06	+ .11	52.3	+ 4.6	85	21	62	28	15	43	36	47	42	71	2.21	− 1.0	10	6,736	se.	38	nw.	22	11	9	11	5.6	4.9	0.0
Chicago	823	140	310	29.15	30.03	+ .07	61.7	+ 5.2	93	24	69	39	2	54	31	53	46	62	0.80	− 2.6	10	8,898	n.	38	w.	13	13	10	8	4.3	0.0	0.0
Green Bay	617	109	144	29.36	30.02	+ .07	58.4	+ 3.9	91	22	68	32	15	49	32	52	47	68	1.04	− 2.5	9	8,033	ne.	33	n.	1	7	8	16	6.5	0.0	0.0
Milwaukee	681	125	139	29.30	30.03	+ .07	57.8	+ 4.2	90	22	65	35	2	50	29	51	45	65	1.39	− 2.0	10	7,270	ne.	29	ne.	1	12	9	10	5.1	T.	0.0
Duluth	1,133	11	47	28.83	30.05	+ .09	50.5	+ 1.9	87	21	60	27	14	41	40	46	41	75	2.77	− 0.7	9	9,252	ne.	42	sw.	21	13	6	12	5.1	0.1	0.0
North Dakota.							54.8	+ 0.6										61	2.10	− 0.4										5.1		
Moorhead	940	50	58	29.01	30.02	+ .08	56.6	+ 1.8	89	21	68	26	14	45	35	49	41	61	2.56	− 0.4	8	6,547	se.	36	sw.	20	10	14	7	4.7	T.	0.0
Bismarck	1,674	8	57	28.30	30.03	+ .11	54.8	− 0.4	88	21	66	26	3	44	40	47	40	63	2.72	+ 0.2	14	8,142	e.	46	sw.	20	9	12	10	5.4	T.	0.0
Devils Lake	1,482	11	44	28.43	30.01	+ .07	54.2	+ 1.5	86	21	67	21	14	42	40	47	39	59	1.03	− 1.2	8	7,914	se.	40	sw.	20	16	8	7	3.9	0.0	0.0
Ellendale	1,457	10	56	28.49	30.02	......	54.4	......	85	21	66	23	2	43	37				4.53	......	12	10,829	se.	48	s.	19	7	8	16	6.0	0.0	0.0
Grand Forks	835	12	89	......	......	......	55.8	......	87	21	70	20	3	42	46				1.68	......	6	......	se.	56	sw.	20	22	5	4	......	T.	0.0
Williston	1,878	41	48	27.98	29.96	+ .03	53.8	− 0.5	82	21	64	26	15	44	32	47	40	62	2.08	− 0.2	7	8,091	se.	48	se.	2	9	15	7	5.3	0.0	0.0
Upper Mississippi Valley.							64.6	+ 2.6										65	3.21	− 1.0										5.6		
Minneapolis	918	102	208	29.01	29.99	......	60.0	......	91	22	69	30	2	51	29				3.49	− 0.4	16	8,447	se.	33	ne.	1	8	9	14	6.1	T.	0.0
St. Paul	837	236	261	29.11	30.01	+ .07	59.8	+ 1.6	90	22	69	31	2	51	31				3.38	− 0.2	15	8,646	se.	39	sw.	20	9	10	12	5.6	T.	0.0
La Crosse	714	11	48	29.24	30.01	+ .07	61.6	+ 2.1	92	22	72	31	16	52	31				5.96	+ 2.2	15	3,163	s.	20	sw.	30	6	7	18	6.8	0.0	0.0
Madison	974	70	78	29.00	30.04	+ .08	60.4	+ 2.8	87	29	70	34	15	51	31	54	49	70	5.13	+ 1.5	12	6,365	s.	39	n.	2	4	12	15	6.6	0.0	0.0
Wausau	1,247	4	......	28.70	30.03	......	57.8	......	87	21	69	28	16	47	36				3.99	......	10	......	n.	......	......	......	5	15	11	6.5	T.	0.0
Charles City	1,015	10	49	28.95	30.02	+ .08	61.2	+ 1.7	91	22	72	31	16	51	31	55	50	72	5.96	+ 1.0	11	4,745	se.	27	nw.	26	8	15	8	5.7	0.0	0.0
Davenport	606	71	79	29.36	30.02	+ .07	65.6	+ 4.1	92	30	76	37	2	55	28	57	51	63	2.69	− 1.5	7	5,425	e.	36	w.	26	11	8	12	5.7	0.0	0.0
Des Moines	861	84	97	29.08	29.98	+ .05	65.4	+ 3.8	93	29	75	36	3	56	30	56	50	63	3.62	− 0.9	8	5,862	sw.	34	sw.	26	7	13	11	5.8	0.0	0.0
Dubuque	698	81	96	29.29	30.04	+ .09	63.6	+ 2.8	91	23	73	35	16	54	30	56	50	66	2.26	− 2.1	11	4,749	s.	30	nw.	23	7	8	16	6.4	0.0	0.0
Keokuk	614	64	78	29.35	30.02	+ .08	66.6	+ 3.4	92	24	76	40	3	57	24	57	51	60	1.72	− 2.5	5	5,187	n.	28	se.	9	8	12	11	5.9	0.0	0.0
Cairo	356	87	93	29.63	30.01	+ .05	68.6	+ 1.1	91	28	78	41	3	60	26	60	54	65	1.68	− 2.2	6	5,649	ne.	31	w.	10	8	10	13	5.8	0.0	0.0
Peoria	609	11	45	29.37	30.03	+ .06	65.1	+ 3.4	93	24	76	34	16	54	32	57	51	65	2.13	− 2.1	7	4,311	s.	23	w.	13	21	5	5	3.3	0.0	0.0
Springfield, Ill	644	10	91	29.34	30.01	+ .06	66.8	+ 3.3	93	31	77	39	2	56	29	58	52	63	1.17	− 3.3	9	5,529	s.	23	ne.	1	10	13	8	5.0	0.0	0.0
Hannibal	534	74	109	29.45	30.02	+ .08	66.6	+ 2.2	92	24	76	39	3	57	28				1.41	− 3.6	6	5,954	sw.	34	ne.	1	14	10	7	4.4	0.0	0.0
St. Louis	567	265	303	29.41	30.01	+ .06	68.5	+ 2.0	92	24	77	40	3	60	22	58	52	60	4.29	0.0	7	7,881	s.	46	ne.	2	16	10	5	3.7	0.0	0.0
Missouri Valley.							63.3	+ 1.3										69	4.18	− 0.1										5.1		
Columbia, Mo	781	11	84	29.19	30.01	+ .07	65.8	+ 1.3	90	28	76	39	3	56	30				4.01	− 0.8	11	4,906	s.	30	ne.	2	15	8	8	4.8	0.0	0.0
Kansas City	963	161	181	28.97	30.00	+ .08	67.0	+ 2.5	93	29	76	40	3	58	24	58	53	64	7.54	+ 2.4	8	7,794	s.	49	sw.	26	15	11	5	3.9	0.0	0.0
St. Joseph	967	11	49	28.95	29.97	......	66.6	......	93	29	77	35	3	56	31	58	53	67	4.71	......	8	5,884	s.	48	w.	26	16	10	5	3.9	0.0	0.0
Springfield, Mo	1,324	98	104	28.63	30.02	+ .09	65.4	+ 0.8	88	28	75	36	3	56	25	59	55	71	4.06	− 1.5	8	6,883	se.	40	se.	10	19	7	5	3.3	0.0	0.0
Iola	984	11	50	28.96	29.99	+ .07	67.6	+ 3.1	91	29	79	37	3	57	30				4.85	− 0.2	6	4,893	s.	36	w.	26	11	15	5	4.7	0.0	0.0
Topeka	987	92	107	......	......	......	66.2	+ 1.2	92	28	77	36	3	56	30				3.71	− 1.2	5	7,722	s.	46	w.	26	11	11	9	5.0	0.0	0.0
Drexel	1,299	10	53	28.59	29.97	......	63.4	......	92	29	74	33	3	53	29	56	52	69	3.04	......	10	8,269	s.	44	e.	8	9	11	11	5.7	0.0	0.0
Lincoln	1,189	11	84	28.70	29.95	+ .04	65.3	+ 2.4	96	28	76	34	3	55	39	57	51	66	3.10	− 1.2	8	7,840	se.	36	nw.	1	8	11	12	5.7	0.0	0.0
Omaha	1,105	115	122	28.82	29.98	+ .06	65.9	+ 3.4	94	29	75	37	14	56	30	58	54	70	3.18	− 1.3	9	5,793	s.	36	nw.	1	9	12	10	5.6	0.0	0.0
Valentine	2,598	47	54	27.26	29.96	+ .06	57.0	− 0.9	87	22	68	33	2	46	36	50	45	68	2.28	− 1.0	13	8,753	se.	48	se.	7	5	15	11	6.2	0.0	0.0
Sioux City	1,135	94	164	......	29.99	+ .07	62.4	+ 1.6	92	29	72	33	3	53	32				3.96	− 0.4	13	8,747	s.	......	......	......	6	14	11	......	0.0	0.0
Huron	1,306	59	74	28.61	30.01	+ .09	58.2	+ 0.9	87	22	69	31	2	48	34	52	48	73	2.66	− 0.3	13	7,289	se.	42	s.	19	10	11	10	5.1	0.0	0.0
Pierre	1,572	70	75	28.31	29.97	+ .06	58.2	− 1.1	87	22	68	28	2	49	33	53	49	75	4.79	+ 2.7	14	8,172	e.	40	n.	11	7	6	18	6.7	0.0	0.0
Yankton	1,233	49	57	28.66	29.97	+ .05	60.9	+ 0.9	91	29	71	32	4	51	34				6.04	+ 2.1	13	5,894	nw.	35	sw.	25	13	8	10	6.2	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, May, 1911*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Elevation of instruments. Thermometer above ground.	Elevation of instruments. Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Pressure. Sea level, reduced to mean of 24 hours.	Pressure. Departure from normal.	emperature of the air. Mean max. + mean min. ÷ 2.	emperature of the air. Departure from normal.	emperature of the air. Maximum.	emperature of the air. Date.	emperature of the air. Mean maximum.	emperature of the air. Minimum.	emperature of the air. Date.	emperature of the air. Mean minimum.	emperature of the air. Greatest daily range.	Mean wet thermometer	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Days with 0.01 inch or more.	Wind. Total movement.	Wind. Prevailing direction.	Wind. Maximum velocity. Miles per hour.	Wind. Maximum velocity. Direction.	Wind. Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F			°F.	°F	°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							52.7	+ 0.2										63	2.65	+ 0.3										6.2		
Billings	3,140	5					55.2		88	2	69	22	1	41	47				3.30		10						3	16	12		0.0	0.0
Havre	2,505	11	44	27.32	29.94	+ .04	53.8	− 0.3	84	25	65	30	3	42	36	46	40	66	2.17	+ 0.1	11	5,719	e.	36	w.	2	10	13	8	5.5	T.	0.0
Helena	4,110	87	112	25.73	29.90	− .03	51.6	0.0	78	25	62	27	1	41	40	43	35	60	1.64	− 0.3	14	5,468	sw.	34	sw.	2	4	6	21	7.5	T.	0.0
Kalispell	2,973	48	56		29.87	− .01	53.0	+ 2.0	79	25	64	29	3	42	36				0.57	− 1.5	8	4,337	nw.	35	sw.	2	7	16	8		0.0	0.0
Miles City	2,371	26	48																													
Rapid City	3,259	50	58	26.58	29.98	+ .08	53.4	− 0.8	88	21	63	30	1	44	36	45	38	61	2.50	− 0.4	15	6,954	n.	37	s.	7	5	11	15	6.9	0.0	0.0
Cheyenne	6,088	84	101	23.96	29.87	+ .02	50.4	− 0.6	75	27	62	30	2	39	36	43	37	66	2.40	0.0	11	6,429	s.	45	w.	7	5	17	9	5.7	T.	0.0
Lander	5,372	60	68	24.56	29.85	− .03	54.0	+ 2.0	78	5	66	30	1	42	38	43	34	55	5.56	+ 2.7	13	4,553	sw.	36	sw.	31	9	15	7	5.4	T.	0.0
Sheridan	3,790	10	47	26.03	29.90		53.4		81	2	64	22	1	42	44	46	39	65	2.98		12	6,017	nw.	42	se.	1	8	11	12	5.7	0.0	0.0
Yellowstone Park	6,200	11	48	23.81	29.89	− .02	44.6	− 2.8	67	25	55	26	1	34	39	38	32	67	4.48	+ 2.6	16	5,360	sw.	28	sw.	21	4	11	16	7.0	11.3	0.0
North Platte	2,821	11	51	27.05	29.95	+ .07	61.0	+ 2.0	94	28	73	34	3	49	46	52	45	65	1.89	− 1.2	12	3,317	se.	20	sw.	19	10	7	14	5.6	T.	0.0
Middle Slope.							64.6	+ 1.7										60	1.45	− 2.4										5.3		
Denver	5,292	106	113	24.67	29.86	+ .02	57.6	+ 0.9	83	21	69	38	1	46	32	47	39	56	0.60	− 1.9	7	5,802	n.	42	se.	6	5	17	9	5.7	0.0	0.0
Pueblo	4,685	80	86	25.21	29.82	− .01	62.2	+ 2.7	93	28	77	36	3	48	44	48	37	49	0.98	− 0.7	2	5,299	e.	32	w.	7	8	17	6	5.5	0.0	0.0
Concordia	1,392	50	58	28.52	29.98	+ .07	65.8	+ 2.1	96	28	76	36	4	56	37	57	51	64	2.51	− 2.2	7	6,651	s.	32	s.	19	5	18	8	5.8	0.0	0.0
Dodge City	2,509	11	51	27.39	29.96	+ .09	64.8	+ 1.3	92	28	77	37	3	53	36	55	49	64	1.36	− 2.0	9	9,003	se.	34	se.	6	9	17	5	4.5	0.0	0.0
Wichita	1,358	139	158	28.54	29.95	+ .05	67.8	+ 1.9	91	28	77	42	3	58	32	59	53	63	1.41	− 3.5	4	9,769	s.	70	sw.	26	8	20	3	4.8	0.0	0.0
Altus	1,410	5																														
Broken Arrow	765	11	52	29.18	30.00		68.6		90	28	79	40	3	58	29				1.47		5	6,749	s.	38	n.	1	7	16	8	5.4	0.0	0.0
Muskogee	652	4																														
Oklahoma City	1,214	10	47	28.71	29.97	+ .08	69.6	+ 1.5	90	12	80	43	3	59	32	60	55	64	1.85	− 3.9	7	8,979	s.	40	s.	8	7	16	8	5.3	0.8	0.0
Southern Slope.							70.8	+ 0.2										55	1.52	− 1.2										4.8		
Abilene	1,738	10	52	28.14	29.92	+ .05	73.6	+ 1.7	96	31	85	49	3	62	32	61	54	58	1.46	− 2.3	6	8,251	s.	34	w.	27	8	14	9	5.5	0.0	0.0
Amarillo	3,676	10	49	26.23	29.90	+ .06	65.4	+ 1.1	92	31	78	37	2	53	37	55	48	60	2.09	− 1.6	10	9,516	se.	35	se.	6	16	12	3	3.9	0.0	0.0
Del Rio	944	64	71	28.94	29.91	+ .07	75.7	− 1.2	95	31	85	55	10	66	38				1.05	− 1.3	3	6,414	se.	34	ne.	9	8	11	12	5.8	0.0	0.0
Roswell	3,566	75	85	26.29	29.84	+ .02	68.4	− 1.0	94	31	82	43	3	54	42	53	40	48	1.49	+ 0.3	10	7,398	s.	36	s.	20	13	13	5	4.2	0.0	0.0
Southern Plateau.							63.5	− 2.4										36	0.69	+ 0.3										3.0		
El Paso	3,762	110	133	26.10	29.78	.00	71.9	− 0.2	93	29	85	48	8	58	38	51	29	27	0.31	0.0	4	8,159	w.	41	w.	6	21	9	1	2.4	0.0	0.0
Santa Fe	7,013	57	66	23.22	29.80	− .01	56.0	− 0.7	78	30	67	30	8	44	32	42	29	43	2.35	+ 1.2	11	7,846	se.	47	s.	6	11	11	9	4.9	0.0	0.0
Flagstaff	6,908	10	59	23.29	29.81	+ .03	47.2	− 3.5	73	27	62	27	7	32	40				2.00		5	7,156	nw.	37	s.	17	17	11	3		4.1	0.0
Phoenix	1,108	76	81	28.65	29.79	+ .01	73.6	− 1.2	101	15	89	48	8	58	39	53	33	27	0.17	+ 0.1	2	4,426	w.	30	w.	20	28	1	2	1.7	0.0	0.0
Yuma	141	9	54	29.66	29.81	+ .02	73.0	− 3.8	103	26	88	46	7	58	41	56	42	42	0.06	0.0	2	3,912	w.	32	nw.	5	26	5	0	1.4	0.0	0.0
Independence	3,957	9	41	25.85	29.84	.00	59.4	− 5.1	86	15	73	32	18	46	37	45	32	43	0.54	+ 0.4	6	5,130	s.	34	nw.	16	13	11	7	4.5	0.0	0.0
Middle Plateau.							56.0	− 0.5										48	1.76	+ 0.6										5.3		
Reno	4,532	74	81	25.36	29.86	− .06	53.2	− 0.4	81	13	66	29	2	40	37	42	31	50	2.57	+ 1.8	11	6,008	w	38	sw	1	14	8	9	4.9	T.	0.0
Tonopah	6,090	12	20	23.96	29.82		51.4		79	12	62	28	6	41	34	41	30	49	2.50	+ 1.1	8	6,779	se	36	nw	16	6	21	4	5.1	5.0	0.0
Winnemucca	4,344	18	56	25.49	29.84	− .07	54.1	− 0.3	83	26	68	30	17	41	30	43	34	56	1.18	+ 0.2	9	5,575	sw	39	sw	1	11	8	12	5.4	0.0	0.0
Modena	5,479	10	43	24.50	29.80	− .02	52.0	− 2.5	78	27	66	29	7	38	39	39	26	45	1.25	+ 0.4	7	10,462	sw	50	s	16	12	13	6	4.6	0.4	0.0
Salt Lake City	4,360	163	203	25.49	29.80	− .06	59.1	+ 0.8	82	27	69	38	7	49	31	46	35	46	1.95	0.0	10	6,472	se	42	s	6	7	12	12	6.1	0.0	0.0
Grand Junction	4,602	60	68	25.27	29.80	− .03	61.6	0.0	89	28	74	38	8	49	38	47	32	41	1.12	+ 0.2	11	5,662	se	42	sw	21	9	9	13	5.7	T.	0.0
Northern Plateau.							56.9	0.0										55	1.56	− 0.1										5.4		
Baker	3,471	48	53	26.35	29.92	− .04	51.8	+ 1.1	75	24	64	28	11	40	42	44	36	62	2.99	+ 1.3	10	4,785	ne	25	n	7	8	13	10	4.8	0.0	0.0
Boise	2,739	78	86	27.03	29.87	− .06	57.2	− 0.4	81	14	69	35	3	46	35	48	40	58	2.15	+ 0.9	7	4,319	w	26	w	7	13	8	10	4.9	0.0	0.0
Lewiston	757	40	48	29.10	29.90	− .06	60.1	− 0.7	86	24	73	38	3	47	39				1.34	− 0.3	8	2,678	e	32	nw	26	7	9	15	5.9	0.0	0.0
Pocatello	4,477	60	68	25.35	29.82	− .07	55.0	− 0.5	76	28	66	31	3	44	37	45	36	57	2.47	+ 0.3	15	5,875	se	38	sw	31	5	10	16	6.7	0.0	0.0
Spokane	1,929	101	110	27.86	29.89	− .07	56.7	+ 0.6	84	24	70	35	12	44	35	46	36	52	0.23	− 1.4	5	5,109	sw	33	w	10	10	12	9	5.2	T.	0.0
Walla Walla	991	57	65	28.84	29.91	− .05	60.4	− 0.3	86	24	72	37	3	48	34	49	37	46	0.19	− 1.6	5	3,845	sw	28	s	2	10	14	7	5.0	0.0	0.0
North Pacific Coast Region.							53.1	− 0.7										76	1.78	− 0.8										5.6		
North Head	211	11	56	29.82	30.04	+ .01	49.8	− 1.4	61	28	53	40	3	46	13	48	47	89	1.69	− 0.7	12	11,784	n	60	s	9	5	20	6	5.5	0.0	0.0
Port Angeles	29	8	53																													
Seattle	125	215	250	29.90	30.04	− .03	53.6	− 1.4	75	30	62	39	3	46	26	48	42	70	1.93	− 0.4	10	6,266	n	42	sw	10	7	13	11	5.7	0.0	0.0
Tacoma	213	113	120	29.80	30.03	+ .01	53.6	− 0.9	75	13	62	36	3	45	32	48	43	72	2.10	− 0.4	9	4,525	n	30	sw	2	9	13	9	5.9	0.0	0.0
Tatoosh Island	86	7	57	29.94	30.04	+ .03	48.8	− 0.8	62	28	53	40	10	45	18	47	46	92	2.24	− 1.8	13	8,210	w	44	sw	10	10	9	12	5.8	0.0	0.0
Yakima	1,071	4																														
Medford	1,425	4					56.0		87	24	69	31	2	43	46	48	40	60	2.47		12						9	4	18		0.0	0.0
Portland, Oreg	153	68	106	29.85	30.01	− .02	57.1	+ 0.3	80	29	66	40	11	48	32	50	43	65	0.99	− 1.4	10	4,674	nw	24	sw	2	8	9	14	6.2	0.0	0.0
Roseburg	510	9	57	29.46	30.02	− .01	55.9	− 0.1	86	24	68	37	27	44	41	49	42	68	1.75	− 0.3	8	2,702	n	20	n	22	11	11	9	4.7	0.0	0.0
Middle Pacific Coast Region.							55.9	− 2.3										73	1.34	+ 0.1										5.1		
Eureka	62	73	89	29.98	30.05	.00	50.8	− 1.3	60	10	55	40	4	47	15	48	46	86	2.54	0.0	8	5,381	n	33	n	27	3	12	16	7.1	0.0	0.0
Mount Tamalpais	2,375	11	18																													
Point Reyes Light	490	7	18	29.43	29.94		49.8	− 1.8	58	24	54	42	18	46	12				0.51		6	17,034	nw	59	nw	14	6	14	11	6.5	0.0	0.0
Red Bluff	332	50	56	29.55	29.90	− .05	62.8	− 3.7	91	12	75	41	2	51	35	54	46	61	2.05	+ 0.7	8	4,126	se	27	se	1	23	5	3	3.1	0.0	0.0
Sacramento	69	106	117	29.85	29.92	− .02	60.7	− 2.2	91	12	73	41	2	49	37	52	46	66	0.75	− 0.2	3	6,479	s	34	sw	1	18	9	4	3.2	0.0	0.0
San Francisco	155	208	243	29.80	29.98	− .01	54.4	− 1.1	71	11	60	44	1	48	22	50	46	70	0.52	− 0.3	7	8,590	w	41	w	15	11	8	12	5.6	0.0	0.0
San Jose	141	12	110	29.85	30.00		57.0	− 3.7	82	20	68	35	3	46	38				0.82	+ 0.1	7	4,878	nw	42	s	1	14	3	14	5.1	0.0	0.0
South Pacific Coast Region.							59.2	− 2.8										72	2.03	+ 1.4										5.0		
Fresno	327	89	98	29.57	29.92	.00	63.6	− 4.8	94	27	76	42	3	51	35	52	42	52	0.69	+ 0.1	6	6,195	nw	31	nw	1	18	8	5	2.9	0.0	0.0
Los Angeles	338	159	191	29.60	29.97	+ .02	58.8	− 3.7	76	11	65	46	7	52	22	54	52	81	3.57	+ 3.1	7	4,573	sw	25	e	5	5	12	14	6.4	0.0	0.0
San Diego	87	62	70	29.87	29.96	+ .01	58.4	− 2.4	65	12	62	49	8	54	13	54	51	80	2.54	+ 2.1	7	5,562	sw	28	s	20	3	15	13	6.4	0.0	0.0
San Luis Obispo	201	32	40	29.78	29.98	− .02	56.2	− 0.5	86	12	66	38	4	47	39	49	45	76	1.32	+ 0.4	7	3,637	sw	19	w	2	13	12	6	4.2	0.0	0.0
West Indies.																																
San Juan, P. R	82	8	54	29.89	29.97		77.5		90	5	83	70	20	72	16				7.23	+ 2.5	20	8,391	e	31	e	15	4	15	12	6.5	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86	+ .02	80.2	− 0.4	91	11	87	70	8	74	19	75	73	85	8.60	+ 0.4	19	5,426	nw	32	nw	11	0	14	17	7.4	0.0	0.0
Colon	36	7	97	29.83	29.86	+ .02	81.1	+ 0.9	91	31	86	72	24	76	16	76	74	81	13.61	+ 1.1	18	6,650	n	26	nw	7	2	14	15	7.5	0.0	0.0
Alaska.																																
Juneau	80	11	49				47.2		71	16	55	33	9	39	34	32	37	71	6.11		19	3,260	se	15	n	10	6	4	21	7.4	T.	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, May, 1921.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Temperature of the air. Departure from normal.	Temperature of the air. Mean maximum.	Temperature of the air. Mean minimum.	Temperature of the air. Highest.	Temperature of the air. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.97	30.02	+0.05	47.3	+2.4	67.0	38.2	71	30	1.28	−1.59	0.0
Halifax, N. S.	88	29.90	30.01	+ .03	51.5	+3.1	62.3	40.6	82	31	4.28	0.00	T.
Yarmouth, N. S.	65	29.92	29.99	+ .01	49.8	+2.2	58.2	41.4	73	32	1.55	−2.25	0.0
Charlottetown, P. E. I.	38	29.96	30.00	+ .01	49.7	+2.8	58.7	40.7	77	32	1.86	−1.05	0.0
Chatham, N. B.	28	29.99	30.02	+ .07	51.8	+3.3	63.9	39.8	84	28	2.19	−1.02	0.4
Father Point, Que.	20	29.95	29.98	+ .05	47.8	+3.8	56.5	39.1	68	28	1.26	−1.32	0.0
Quebec, Que.	296	29.70	30.02	+ .08	55.3	+5.4	66.4	44.2	87	34	0.92	−2.16	0.0
Montreal, Que.	187	29.79	29.99	+ .05	59.4	+4.7	69.7	49.2	88	40	0.47	−2.48	0.0
Stonecliffe, Ont.	489	29.41	30.02	+ .09	51.2	−1.1	71.3	31.1	94	18	1.10	−1.41	0.0
Ottawa, Ont.	236	29.74	30.00	+ .07	59.8	+4.9	71.8	47.9	92	36	2.83	+0.24	0.0
Kingston, Ont.	285	29.70	30.01	+ .05	57.4	+4.5	66.1	48.8	82	37	1.62	−1.06	0.0
Toronto, Ont.	379	29.61	30.01	+ .03	60.0	+6.8	79.3	40.7	87	33	1.88	−1.16	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.71	30.03	+ .08	48.7	+3.0	63.3	34.2	87	16	2.10	+0.15	5.5
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.31			54.6	+3.9	63.6	45.6	82	30	0.95	−1.49	0.0
Parry Sound, Ont.	688	29.33	30.02	+ .07	56.6	+5.5	68.5	44.7	86	29	1.58	−1.35	0.0
Port Arthur, Ont.	644	29.34	30.05	+ .09	50.4	+4.5	60.7	40.1	80	24	3.31	+1.16	T.
Winnipeg, Man.	760	29.20	30.04	+ .08	54.2	+2.6	65.9	41.6	84	24	1.76	−0.52	0.1
Minnedosa, Man.	1,690	28.21	30.03	+ .07	51.9	+3.5	63.8	40.0	79	24	3.34	+1.89	T.
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.73	29.97	+ .03	51.9	+2.1	63.9	40.0	80	22	2.83	+1.18	1.2
Medicine Hat, Alb.	2,144	27.60	29.85	− .04	55.7	+1.5	68.7	42.8	89	28	1.62	+0.31	0.0
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.39	29.99	+ .07	52.6	+1.9	64.8	40.4	82	27	2.13	+0.37	0.0
Calgary, Alb.	3,428	26.38	29.94	+ .06	49.9	+0.9	62.0	37.8	82	26	0.73	−1.04	2.0
Banff, Alb.	4,521												
Edmonton, Alb.	2,150	27.61	29.88	.00	50.8	0.0	64.0	37.6	78	27	1.27	−0.28	2.4
Prince Albert, Sask.	1,450	28.41	29.98	+ .03	53.1	+4.5	63.1	43.1	80	27	3.50	+2.24	4.0
Battleford, Sask.	1,592	28.20	29.93	+ .01	52.8	+1.8	64.4	41.2	81	30	2.36	+0.74	1.0
Kamloops, B. C.	1,262	28.67	29.95	+ .06	59.1	0.0	73.3	45.0	89	34	0.96	+0.23	0.0
Victoria, B. C.	230	29.76	30.02	+ .02	52.0	−0.5	59.3	44.6	72	39	1.47	−0.01	0.0
Barkerville, B. C.	4,180	25.62	29.92	+ .08	42.9	−2.6	54.1	31.8	66	24	2.96	+0.44	21.3
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.91	30.07	+ .05	69.9		75.5	64.3	80	61	8.07	+3.41	0.0

SEISMOLOGICAL REPORTS FOR MAY, 1921.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, June 30, 1921.]

TABLE 1.—*Noninstrumental earthquake reports, May, 1921.*

[Note: No reports received for May.]

TABLE 2.—*Instrumental seismological reports, May, 1921.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols, see REVIEW for January, 1921, p. 47.]

COLORADO. *Sacred Heart College, Denver.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 14		L_N	22 19 30					P and S indiscernible.
		L_E	22 19 ..					
		M_N	22 19 30			*2,500		
		M_E	22 22 ..	15	*3,500			
		C_N	22 26 ..	12				
		C_E	22 25 ..					
		F_N	22 31 ..					
		F_E	22 33 ..					
21								Wavelets at intervals on NS.

* Trace amplitude.

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		P	5 46 18					
		S_E	5 50 50					
		S_N	5 50 48					
		S_R	5 56 44					
		eL	5 59 00	9				
		M_E1	6 00 ..	10	*2,900			
		M_N	6 01 05	7		*1,000		
		M_E2	6 00 33	9	*2,900			
		F	7 25 ..					
14		e	21 15 ..					Heavy micros.
		eL_E	21 20 ..	19				
		L_N	21 25 11	19				
		F	21 55 ..					
14		e	22 16 11					
		L_E	22 30 07	8				
		L_N	22 30 03	11				
		F	23 10 ..					
20		e_N	0 59 44					Very heavy micros
		iS	1 07 04					
		F	2 *ca.*					
21		e	9 01 ..					Heavy micros.
		eL_N?	9 31 30					
		F	10 *ca.*					
21		e_E	22 44 47					Heavy micros.
		e_N	22 47 10					
		L_E	23 16 33	16				
		L_N	23 17 16	16				
		F	23 45 ..					
28		e_N	21 08 49					Early portion of quake very doubtful.
		S_E?	21 12 16					
		S_N?	21 12 09					
		eL_E	21 13 30	7				
		eL_N	21 13 30	6				
		M_E	21 13 55	6	*1,900			
		M_N	21 13 54	6		*2,700		
		F	21 58 ..					

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		P	5 45 54				3,100	Confused record.
		S	5 50 42					
		L?	5 53 23					
		F	6 50 *ca.*					
14		eLn	21 24 40					
		F	21 29 00					
14		P?	22 15 30					Superimposed disturbance.
		S?	22 30 ..					
		F	22 40 ..					
20		e	1 02 55					
		S	1 06 56					
		F	1 20 ..					
22		P	18 27 30				2,300	
		S	18 31 22					
		F	18 35 *ca.*					
28		e	21 10 15					
		F	21 35 *ca.*					

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		P	5 44 46				3,100	Confused record.
		S	5 49 38					
		L?	5 52 40					
		M	5 56 10		*15,000			
		F	8 10 *ca.*					
12		P	3 59 50				8,600	
		S	4 09 38					
		eL	4 26 30					
		L	4 36 ..	24				
		L	4 49 ..	16				
		F	6 15 *ca.*					
14		P						Lost in changing sheets before 13:30.
		F	14 15 *ca.*					
14		e	20 44 ..					
		F						Lost in next quake.
14		eL	21 16 ..	16				Many waves of same period until 22:10*ca.*
		F						Merged in next quake.
14		P	22 15 10				2,800	Apparently 2 shocks superimposed.
		S	22 19 38					
		L?	22 21 50					
		F	23 50 *ca.*					
16		e?	15 43 ..					
		L	16 08 ..	22				
		F	17 20 *ca.*					
20		P	0 56 40				9,000	
		S	1 06 50					
		L	1 24 00					
		F	2 40 ..					
21		P	9 02 17				8,400	
		S	9 11 58					
		L	9 27 15					
		F	11 *ca.*					
21		e	11 23 ..					
		L	11 31 30					
		F	11 55 *ca.*					
21		P	22 37 20				8,300	
		S	22 46 52					
		L	23 02 15					
22		F	1 10 *ca.*					
22		e	18 33 10					
		L	18 36 ..					
		F	19 10 *ca.*					
28		P	21 00 03				2,900	
		S	21 04 40					
		L	21 08 ..					
		F	22 10 *ca.*					

MISSOURI. *St. Louis University, St. Louis.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		eP	5 44 15				2,700	
		S_N	5 48 30					
		S_E	5 48 36					
		L	5 49 54					
		M_E	5 52 06	12	*18,000			
		M_E	5 54 ..		*20,000			
		M_N	5 52 06	12				
		M_N	5 53 48	18		*14,000		
		F_N	6 15 ..					
		F_E	6 45 ..					
28		eP_E	20 59 54				3,000	Phases on NS indeterminable owing to tangling.
		eS	21 04 48					
		eL	21 08 30					
		M	21 11 36	9	*6,000			
		F	21 47 ..					

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, May, 1921*—Continued.

NEW YORK. *Fordham University, New York.*

1921		H. m. s.	Sec.	μ	μ	Km.	
May 1	P_E	12 46 42					Clock correction not known.
	M_E	1 01 30					

CANAL ZONE. *Panama Canal, Balboa Heights.*

1921		H. m. s.	Sec.	μ	μ	Km.	
May 1	P_E	5 46 00					Slight tremor; no record on NS owing to clock stopping.
	F_E	6 45 00					
16							Slight tremors 20:06:34 to 20:17:00
25							Slight tremors 15:39:24 to 15:40:24

VERMONT. *U. S. Weather Bureau, Northfield.*

1921		H. m. s.	Sec.	μ	μ	Km.
May 1	e	5 47 30				
	S	5 52 ..				
	eL	5 54 10				
	F	6 35 *ca.*				
14	e	22 25 00				
	L	22 32 40				
	F	22 50 *ca.*				
28	e	21 12 ..				
	F	21 25 ..				

CANADA. *Dominion Observatory, Ottawa.*

1921		H. m. s.	Sec.	μ	μ	Km.	
May 1	O	5 38 43				3,980	NS component better than EW at all three stations; approx. epicenter, Lat. 18°.5 N., Long. 104°.5 W.
	P	5 46 00					
	PR2	5 47 18					
	S	5 51 46					
	eL	5 56 12					
	M_N	5 58 48					
	M_{EV}	6 01 30					
	L_E	6 09 ..	16				
	L_E	6 17 ..	12				
	L_E	6 30 ..	8				
	F	8 *ca* ..					Lost in micros.
	SASKATOON RECORD.						
	O	(5 38 40)				3,740	
	P_N	5 45 39					
	$PR1_N$	5 46 44					
	S_N	5 51 11					
	L_N	5 54 30					
	HALIFAX RECORD.						
	O	(5 38 43)				4,750	
	eP_N	5 47 00					
	eS_N	5 53 10					
	$SR1_N$	5 56 25					
	eL_N	6 00 ..					
12	e_E	4 00 ..					
	$e?_E$	4 05 40					
	eL_E	4 17 30	(40)				
	L_E	4 30 30					
	L_E	4 35 ..					
	L_E	4 43 ..	23				
	L_E	4 57 ..	18				
	F	5 20 ..					
14	$e?_E$	13 28 30					
	L_E	13 36 ..	16				
	L_E	13 44 ..	16				
	F	14 *ca* ..					
14	$e?_E$	20 44 06					
	e_E	20 48 ..					
	eL	20 54 42					
	F						Merges into next quake.
14	$eL?_E$	21 16 ..					
	L	21 24 ..	19				
	L_E	21 28 ..	17				
	L_E	21 33 ..	15				
	L_E	21 40 ..	15				
	L_E	21 44 ..	15				
	L_E	21 51 30	15				
	L_E	21 59 ..	13				
	F	22 15 *ca*					
14	e_{EV}	22 16 30					Periods irregular; difficult to decipher
	e	22 17 36					
	e_E	22 22 00					
	e_E	22 25 36					
	eL	22 28 45					
	F	23 40 ..					

CANADA. *Dominion Observatory, Ottawa*—Continued.

1921		H. m. s.	Sec.	μ	μ	Km.	
May 16	e?	15 39 ..					
	$e?_E$	16 03 ..					
	eL_E	16 16 ..					
	L_E	16 18 ..	18				
	L_E	16 26 ..	15				
	L_E	16 35 ..	15				
	L_E	16 44 ..	15				
	F	17 00 *ca*					
20	$e?_N$	0 56 10					Irregular small periods; small amplitudes.
	e_N	1 01 10					
	S or eL	1 06 25					
	L_E	1 17 ..					
	L_E	1 27 ..	15				
	L_N	1 27 ..	22				
	L_E	1 35 ..	17				
	F	1 55 ..	17				
21	e	9 02 18					
	eL_E	9 18 40					
	L_E	9 30 ..	17				
	L_E	9 37 ..	21				
	L	9 48 ..	19				
	L	10 00 ..	19				
	L	10 11 ..	17				
	F	10 35 ..					
21	eL	11 28 ..	18				
21	$e?_E$	22 41 19					
	e_E	22 47 15					
	e	22 56 ..					
	e_E	23 00 ..					
	eL	23 05 ..	20				
	L_E	23 14 30	18				
	L	23 21 ..	16				
	F	24 00 *ca*					
28	e_N	21 06 22					
	e_{EV}	21 08 55					
	eL	21 10 30					
	M_N	21 12 24					
	L_E	21 32 ..	15				
	L_E	21 37 ..	15				
	F	21 55 ..					

CANADA. *Dominion Meteorological Service, Victoria.*

1921		H. m. s.	Sec.	μ	μ	Km.	
May 1	S?	5 46 34		*3,000			
	L	5 51 00					
	M	5 57 53		*3,000			
	F	6 49 22					
	VERTICAL.						
	P	5 45 45	2.5				
	M	6 01 15	10		7		
	F	6 13 00					
12	P	4 03 26					
	S	4 09 50					
	L	4 21 58					
	M	4 29 00		*500		4,660	
	M_E?	6 03 08					
	F	6 10 19					
14	L	13 25 45 to 13 31 45		*50			
14	P	20 53 44					P may be L phase.
	M	21 04 34		*500			
	F	21 28 10					
14	L	22 20 39					
	M	22 28 10		*1,000			
	F	23 01 37					
16	L	15 55 40					
	L	15 57 22					
	M	15 58 40		*200			Very faint trace.
	F						
20	L	1 21 30					
	L	1 27 36					
	F	1 57 12		*500			
21	L	9 07 16					
	M	9 35 47		*300			
	F	10 21 31					
21	P?	22 32 17					
	S	22 38 41					
	L	22 47 02					
	M	22 56 52		*500		4,660?	
	F	23 16 04					
28	P	19 59 02					
	L	20 04 27					
	M	20 15 06		*200			
	F	20 21 39					

TABLE 2.—*Instrumental seismological reports, May, 1921*—Continued.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921 May 28		P	20 52 38					Prob. off Kyuguo Sd. felt at Estevan Nootka, Quatsino at 20:49.
		L	20 53 17					
		M	20 54 36		*700		300	
		F	21 14 17					
		VERTICAL.						
		P	20 52 50	2				
		L	20 53 30	4				
		M	20 53 44	6		29	300	
		F	21 03 04					
29		P	12 10 18					
		M	12 12 16		*2 0			
		F	12 15 13					

CANADA. *Dominion Meteorological Service, Toronto.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. May 1		P	5 47 12					P phase may be PR.
		S	5 51 48					
		iL	5 59 48					
		eL	6 02 48					
		M	6 06 48		*2,000			
		eL	6 41 00					
		eL	6 43 00					
		F	7 02 12					
12		e?	4 40 00					
		L	4 44 00					
		eL	4 53 24					
		M	4 55 12		*30			
		F	5 24 24					
12		L	5 55 12 to 6 05 00		*50			
14		eL	13 29 24					
		M	13 33 30		*20			
		F						
14		e	20 45 12					
		L	20 48 24					
		M	20 50 00		*20			
		iL	20 54 12					
		F						Merged into next quake.
14		L	21 16 24					
		eL	21 21 00					
		M	21 25 18		*40			
		eL	21 27 18					
		F						
14		e	22 22 12					
		M	22 40 54		*200			
		F	23 03 24					
16		eL	15 55 42					
		eL	16 15 54					
		eL	16 21 06					
		M	16 23 54		*300			
		L?	17 01 24					
		F	17 05 54					
20		L	1 26 12					Times unreliable, no cut-off.
		eL	1 27 24					
		M	1 28 18		*300			
		F						
21		L	9 21 54					
		L	9 49 36					
		eL	10 03 24					
		M	10 05 12		*300			Times unreliable, no cut-off.
		eL	10 22 06					
		L	11 31 54					
		F						Micros.
21		e	22 48 48					Times doubtful, no cut-off.
		e	22 55 30					Micros going on.
		eL	23 05 30					
		M	23 12 48		*600			
		eL	23 15 00					
		F	Micros.					
28		L?	20 14 54		*100			
		F	20 16 54					
28		iL	21 11 30					
		M	21 12 06		*400			
		L	21 26 24					
		F	21 36 30					

No earthquakes were recorded at the following stations during May, 1921:

CALIFORNIA. *Theosophical University*, Point Loma.

Reports for May, 1921, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.
ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.
HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.
MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.
MASSACHUSETTS. *Harvard University*, Cambridge.
NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

TABLE 3.—*Late reports (instrumental).*

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921 Apr. 10		e_E	13 41 47					E. in poor adjustment.
		e_N	13 41 12					
		eL_N	13 42 17					
		M_N	13 42 57	12		1,080		
		C_N	13 48 ..					
		F_E	13 48 ..					
		F_N	14 01 ..					
12		L_E	7 30 50					Neither component in good adjustment.
		L_N	7 31 00					
		M_E	7 31 37		20			
		M_N	7 31 52	9		180		
		F_E	7 36 ..					
		F_N	7 47 ..					

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921 Apr. 5		P	0 21 29					
		L_E	0 22 09					
		L_N	0 22 04					
		M_E	0 22 28		50			
		M_N	0 22 17			60		
		C	0 23 ..					
		F_E	0 29 ..					
		F_N	0 27 ..					
12		c_E	7 44 10		5			
		F_E	7 51 ..					

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

Date		Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921 Apr. 1		e	4 53 ..					Heavy micros.
		eL_E	5 05 30	23				
		F	6 10 ..					
1		L_E	13 06 ..	22				Sheets put on at 12:50, quake in progress.
		L_N	13 10 ..	22				
		F	13 50 ..					Heavy micros.
2		L	10 38 ..	10				
		F	10 50 ..					
3		e_N	2 57 22					EW does not show; heavy micros.
		eL_N	3 02 ..					
		L_N	3 05 06	11				
		F	3 15 ..					
10		eP	13 47 10					
		Se?	13 53 54					Heavy micros.
		eL	13 57 06					
		L	14 02 13	11				
		M_E1	14 05 35	8	*13,000			
		M_N	14 05 20	9		*2,300		
		M_E2	14 06 38	8	*4,600			
		F	14 50					
12		e	7 48 ..					
		i_E	7 56 ..					
		F	8 18 ..					
20		L_E	19 00 ..	24				NS does not show; heavy micros.
		F	19 15 ..					

* Trace amplitude.

TABLE 3.—*Late reports (instrumental)*—Continued.

MASSACHUSETTS. *Harvard University, Cambridge.*

1921.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 2		O	7 *postea*					Very distant. N gives micros, 6 sec. period only.
		L_E	7 51 40	20				
		L	7 59 42	20				
		F?	8 25 *ca*					
8		O	6 *postea*					Record masked by micros.
		$L?_N$	6 49 46					
		L_E	6 35 07					
		F?	7 *ca.*					
9		O	12 *postea*					Records much masked by micros; E too heavily damped.
		L_E	13 28 03	20				
		F?	13 29 30					
19		$L?_E$	15 48 *ca*					Obscure record of distant L waves amid micros on E component only.
		to	16 03 ..					
Feb. 4		O	8 22 13				3,585	32¼° Distance and O mean of N and E records. Probably quake reported as destructive in Tehauntepec, Mexico.
		iP_N	8 29 00					
		eP_E	8 29 03					
		i_E	8 29 24					
		i_N	8 29 30					
		i_N	8 30 22					
		S_N	8 34 12					
		S_E	8 34 39					
		i_N	8 35 08	11				
		i_N	8 35 44	24				
		$eL_E?$	8 36 34	25				
		eL_N	8 37 *ca*					
		M_E	8 39 39	7	*4500			
		M_E	8 41 ..	8	*9125			
		M_E	8 42 15	8	*8500			
		M_E	8 44 ..	8	*10000			
		C_E	8 50 ..					
		F	9 37 ..					
6		O?	4 *postea*				5,325?	No trace on N.
		$S_E?$	5 10 *ca*	6				
		e	5 12 52	10				
		e	5 14 53	14				
		eL_E	5 17 35	16				
		C?	5 21 19					Scant traces after C.
		F?	5 24 *ca*					
6		$L_E?$	21 21 *ca*	*var*				Possibly non-seismic; masked by micros.
			to 31 *ca*					
11		O?	0 11 07				8,500?	P lost in micros; S uncertain; time interpolated; no record on N; F in micros.
		$S_E?$	0 32 39	8				
		L_E	0 47 11	26				
		L	0 57 35	20				
		C_E	1 07 37	16				
		C	1 12 00	16				
			to 19 29					
11		O?	22 37 22				4,045?	P in micros; S may come later; N component failed to register.
		$S_E?$	22 52 26	8				
		e_E	22 55 48	8				
		eL_E	22 59 04	20				
		to	23 01 36					
		L_E	23 02 31	16, 20				
		C_E	23 04 40	8				
		F?	23 06 40					
19		$e_E?$	15 41 44	10				Began and ended in pulsations of doubtful appearances.
		L	15 45 24	22				
		L	15 47 40	20				
		F	16 *postea*					
19		O?	(18 24 20)				11,100?	O from Strassburg and Harvard distance from Strassburg O and Harvard eL. i_N at 18 37 20 indicates over 11200 km.
		e_E	18 37 26	10				
		i	18 56 04					
		eL_E	19 13 00					
		L	19 16 00	28				
		L	19 16 22	20				
		F	20 30 *ca*					
21		O	15 *postea*					Micros mask both components; difficult to interpret.
		e_E	16 03 54	2				
		e	16 05 14	3				
		i	16 10 10	6				
		i	16 11 28	7				
		L_E	16 15 07	9				
		L	16 17 02	11				
		M	16 17 58	14				
		L	16 40 18	8				
			to 42 29					
		F?	17 10 *ca*					
21		O	19 *postea*					Similar to preceding; vague; e and F in micros.
		$S_E?$	19 45 11	16				
		M_E	19 48 42	11	*1500			
		F?	20 02 *ca*					

MASSACHUSETTS. *Harvard University, Cambridge*—Continued.

1921			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 27		O?	18 30 55				8,420?	N and E inconsistent.
		eP_E	18 42 38	6				
		e	18 43 08	7				
		S_E	18 52 19					
		i^E	18 52 28					
		S_N	18 59 01					
		$L_N?$	19 08 32	50?				
		L_E	19 15 08	50				
		L_E	19 17 52	28				
		eM_E	19 23 ..		*6,000			
			to 30 ..					
		eM_E	19 31 ..		*8,250			
			to 33 ..					
		eM_E	19 36 ..		*7,000			
			to 37 ..					
		L_{REP}	20 35 00					
		F	21 40 ..					
Mar. 2		eL_E	3 32 35	28				Distant; possible eS_E? at 3*h*26.6*m*, but isolated from eL; F lost in pulsations, not micros.
		L	3 54 37	20				
		L	4 02 *ca*	15				
		F?	4 26 *ca*					
3		O?	8 36 09				11,420?	102.8° of arc. S? isolated from eL.
		$iS_E?$	9 02 16	8				
		eL_E	9 26 20	40				
		L	9 31 09	30				
		$eM_E?$	9 38 28	28				Flat waves; max. of record.
		L	9 41 *ca*	20				
		L	9 54 22	20				
		F?	10 40 *ca*					F lost in pulsations of irreg. periods.
6		O	7 24 52				3,970	eL and S doubtful; L–P gives dist. 4,200 km. E damped 1.5/1 by magnet; N undamped gives poor record.
		P_E	7 32 08	2				
		S_E	7 37 55	8				
		$eL_E?$	7 43 00	32				
		L_E	7 44 11					
		M_E	7 47 40		*15,000			
		L_E	9 05 13	16				
		F_N	13 56 10					
12		O	10 *postea*					First phases uncertain.
		$P_{RE}?$	10 04 30					
		$S_E?$	10 30 42	8				
		i_E	10 32 28	14				
		eL_E	10 46 00	28				
		L	10 48 42	23				
		F	11 44 12					
24		O	4 *postea*					Steady mass jerked west.
		$e_E?$	5 08 24					
		e_E	5 13 38	7				
		eL_E	5 24 38	16				
		L	5 40 *ca*	12				
		F?	5 55 *ca*					Pulsations.
24		O?	14 44 57				6,220?	56°? N gives M at 15*h* 30*m* *ca.* undamped. Difficult record to interpret.
		$e(S?_E)$	15 02 29	10				
		i_E	15 03 33	11				
		i_E	15 08 39	11				
		$eL_E?$	15 20 08	40				Shorter periods on eL.
		iL_E	15 24 04	20				
		M_E	15 25 36	18	*1,000			6 similar waves.
		M_E	15 28 42	22	*1,000			
		C_E	15 39 *ca*	15				
		F?	16 35 *ca*					
25		O?	0 31 26				7,590?	
		$eP?_N$	0 51 01	3				
		$eP?_E$	0 51 18					
		$iS?_N$	0 51 25	4				
		i_E	0 51 30	4				
		M_N	0 52 23	14		*16,300		Max. or S_R strongly reflected.
		eL_N	1 64 43	20				
		L_E	1 05 00					
		L_N	1 07 35	16				
		L_E	1 07 58	15				
		$F_N?$	1 46 *ca*					
28		O	7 49 15				3,490	31°.4 of arc.
		P_{NE}	7 55 55	2				
		iP_E	7 55 57	10				
		i_E	7 57 04	8				
		i_N	7 57 11	10				Very large amplitudes.
		i_E	7 58 49	10				
		iS_N	8 01 11	11				
		iS_E	8 01 12	10				
		L_{NE}	8 05 01	24				eL not very distinct.
		L_N	8 05 14	41				
		i_{NE}	8 05 07	6				Another quake interfering with L waves; period of undamped pendulum.
		L_E	8 05 23	33				
		M_N	8 08 05	23				
		M_W	8 07.50					
		M_W	8 08 17					
		M_W	8 09 02					
		M_W	8 10 07					
		M_W	8 10 46					

* Trace amplitude.

TABLE 3.—*Late reports (instrumental)*—Continued.

MASSACHUSETTS. *Harvard University, Cambridge*—Continued.

1921			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Mar. 28		M_W	8 11 13					
		L_E	8 16 38					Section of much smaller A running to C.
		C_E	8 22 40					
		F_E	10 08 ..					
29		S_E?	22 56 38	6				No trace on N; e and F obscured by pulsations.
		eL_E?	22 03 00					
		L	23 04 17	20				
		C?	23 11 *ca*					
30		L?	16 10 12					Irregular period pulsations; possibly not seismic.
		L?	16 18 *ca*					
			to 20 *ca*					
		L?	16 22 *ca*					
			to 24 *ca*					
Apr. 1		O	4 *postea*					N out of order; irregular pulsations from early a. m. until midnight.
		e_E	4 53 28	6				
		eL_E	5 09 22	40				
		L	5 14 00	30				
		M?	5 18 10	28				
		M_E	5 23 10	23				
		L	5 27 00	20				
		C_E	5 31 17	15				
		F	6 06 *ca*					
1		O	12 *postea*					Pulsations.
		e?	12 43 24					
		e_E	12 54 45	8				
		eL_E	13 02 26	28				
		L	13 05 00	20				
			13 09 30					Changed record.
		(C)	13 37 00	15				New record begins.
		F	13 52 *ca*					
2		O	9 *postea*					Very distant; P and S masked by micros.
		e_E?	10 05 *ca*					
		e_E	10					
		eL_E	10 32 08	40				
Apr. 2		L	10 34 30	30				
		eM?	10 35 55	24				
		M	10 36 13					
		M	10 43 00	20				
		C	10 48 00	15				
		F	11 11 30					
3		O?	2 45 31				4,100	36°.9 of arc; masked by micros.
		S_E	2 58 49	6				
		eL_E?	3 03 29	15				
		M	3 05 58	15				
		F	3 13 *ca*					
4		e	18 31 *ca*					Pulsations of seismic appearance.
		F	18 41 *ca*					
5		i_E	18 57 52	10				L? waves.
		F	19 01 20					
7		to	{18 29 *ca* / 19 00}	12, 14				Pulsations; independent of local winds and weather.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1921			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Apr. 14		eP	17 58 11					Light local shock; noticed at Vieques as similar to a distant explosion; P shows as a displacement rather than an oscillation.
		L_E	17 58 23					
		L_N	17 58 25					
		M_E	17 58 27		40			
		M_N	17 58 37			30		
		F_E	18 03 ..					
		F_N	18 01 ..					

Chart I. Hydrographs of Several Principal Rivers, May, 1921.

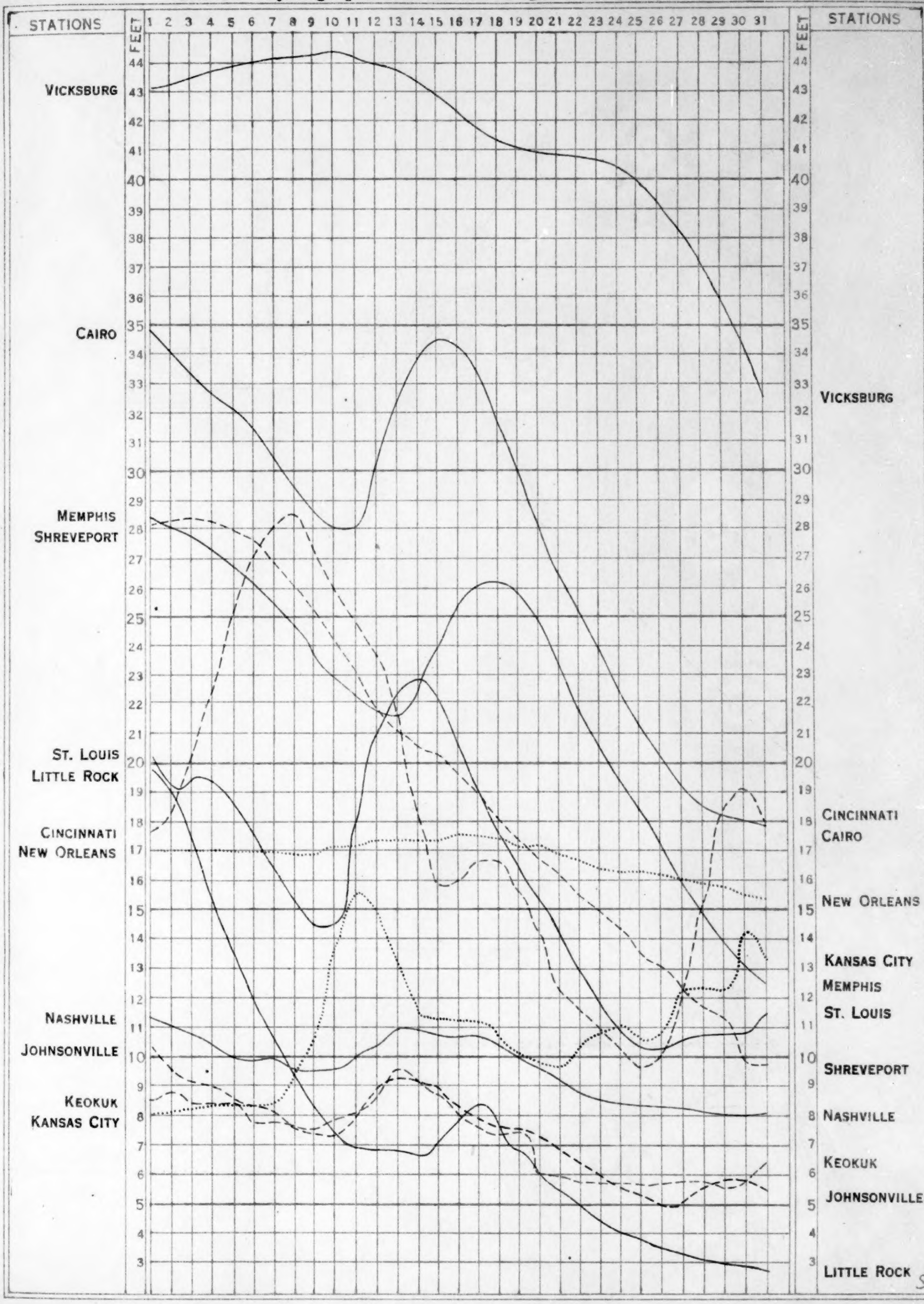


Chart II. Tracks of Centers of High Areas, May, 1921.
(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, May, 1921.
(Plotted by Wilfred P. Day.)

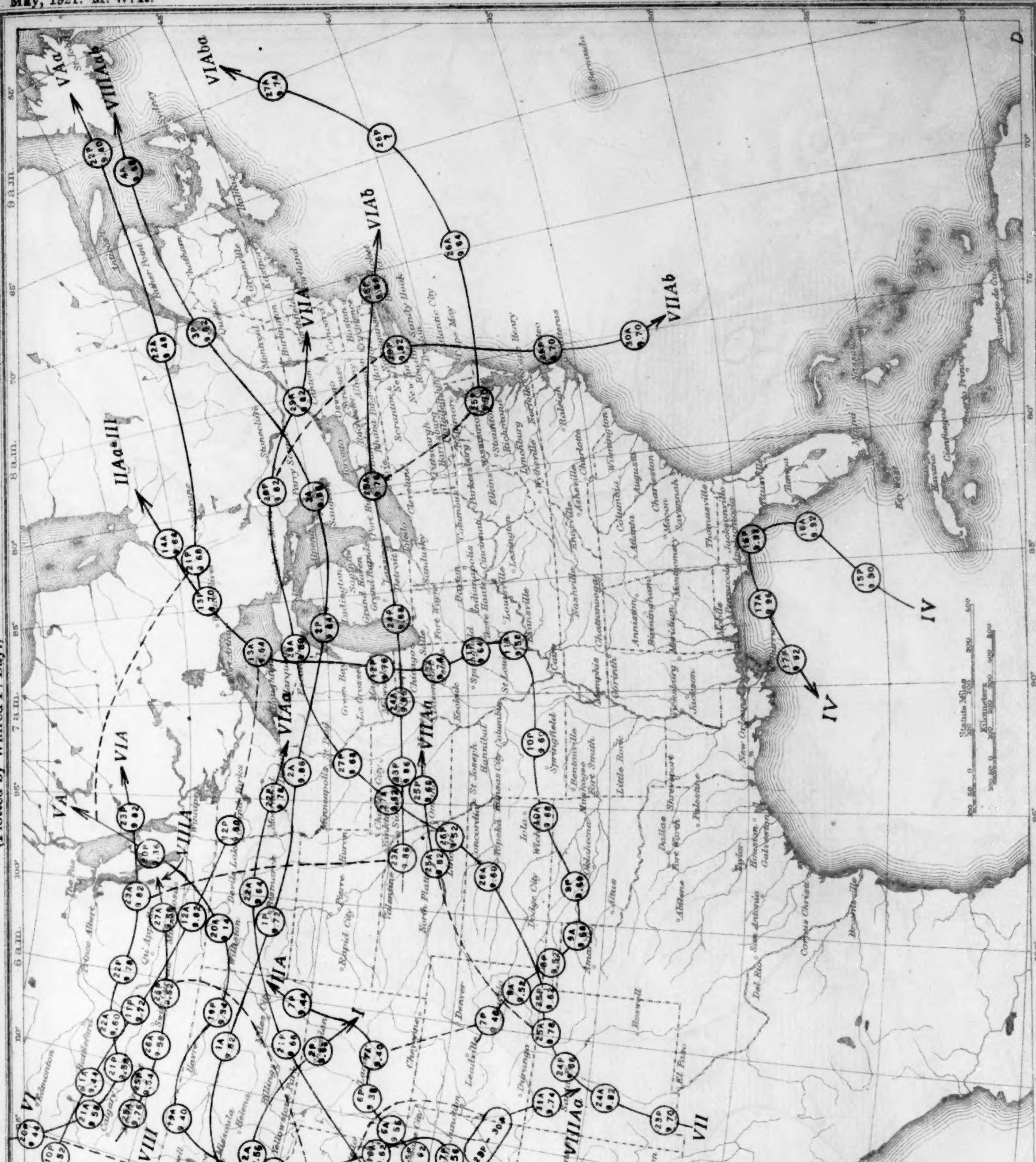


Chart III. Tracks of Centers of Low Areas, May, 1921.
(Plotted by Wilfred P. Day.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, May, 1921.

Shaded portions show excess (+). Unshaded portions show deficiency (−). Lines show amount of excess or deficiency.

Chart V. Total Precipitation, Inches, May, 1921.

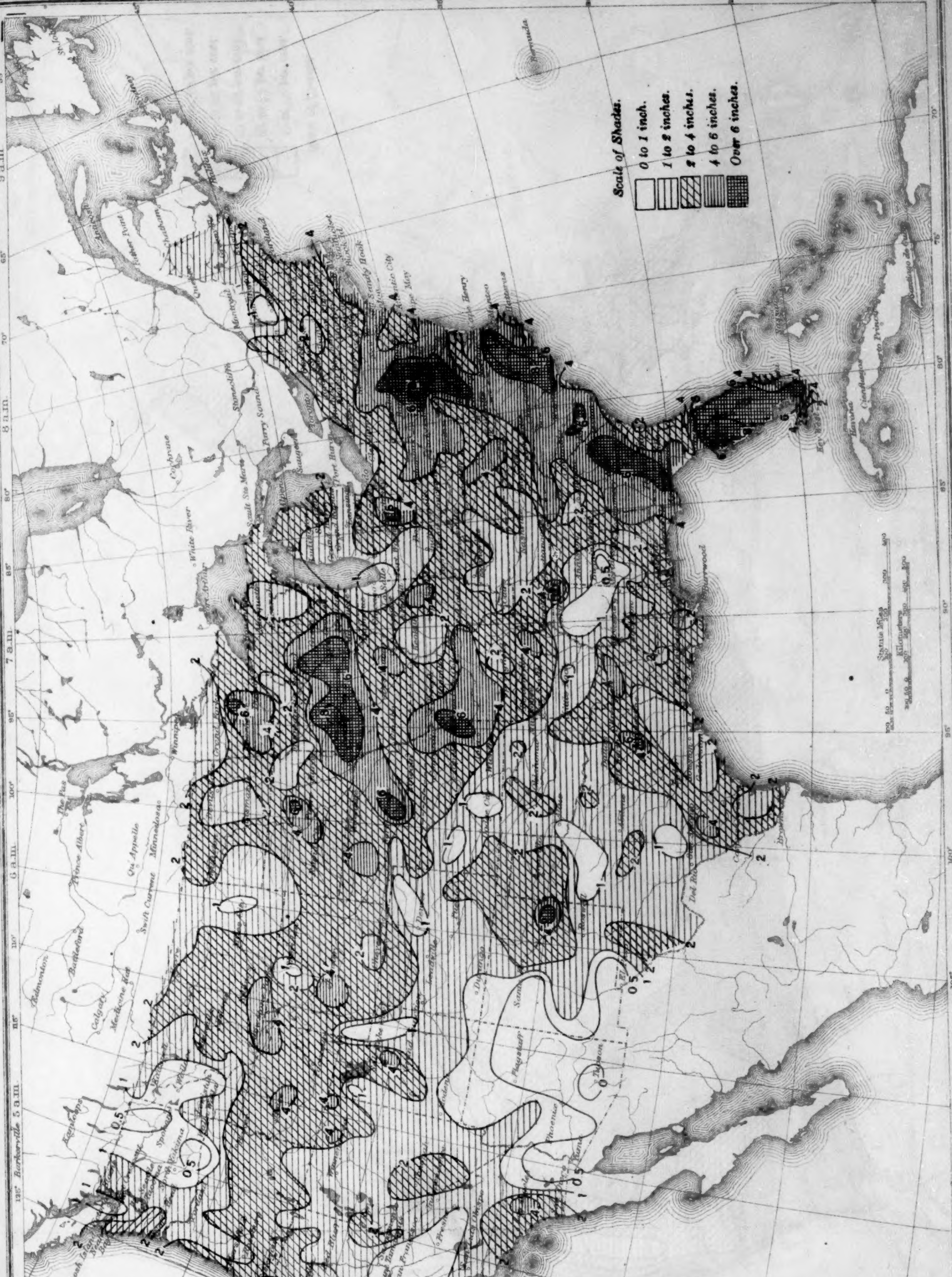


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, May, 1921.

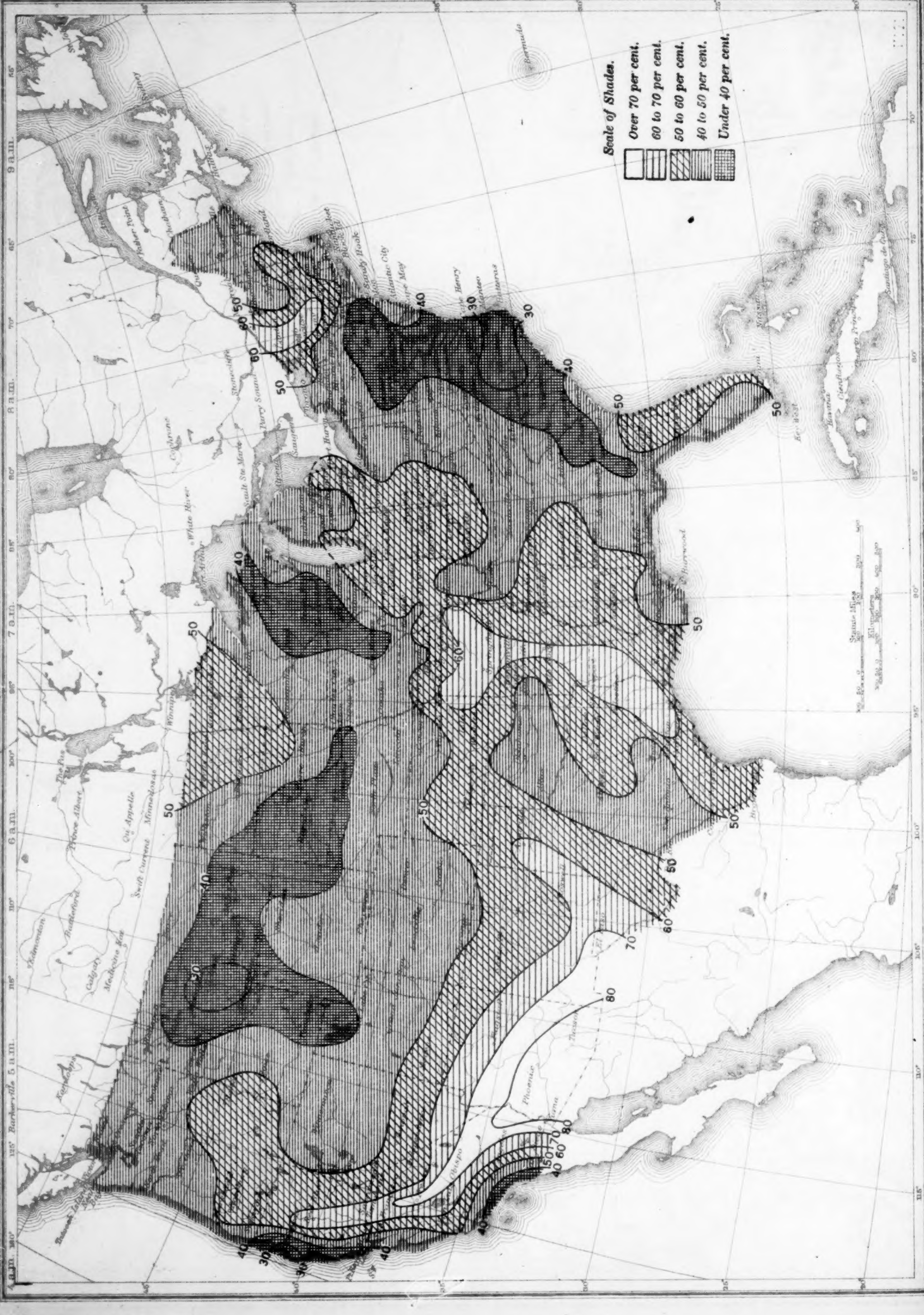


Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, May, 1921.

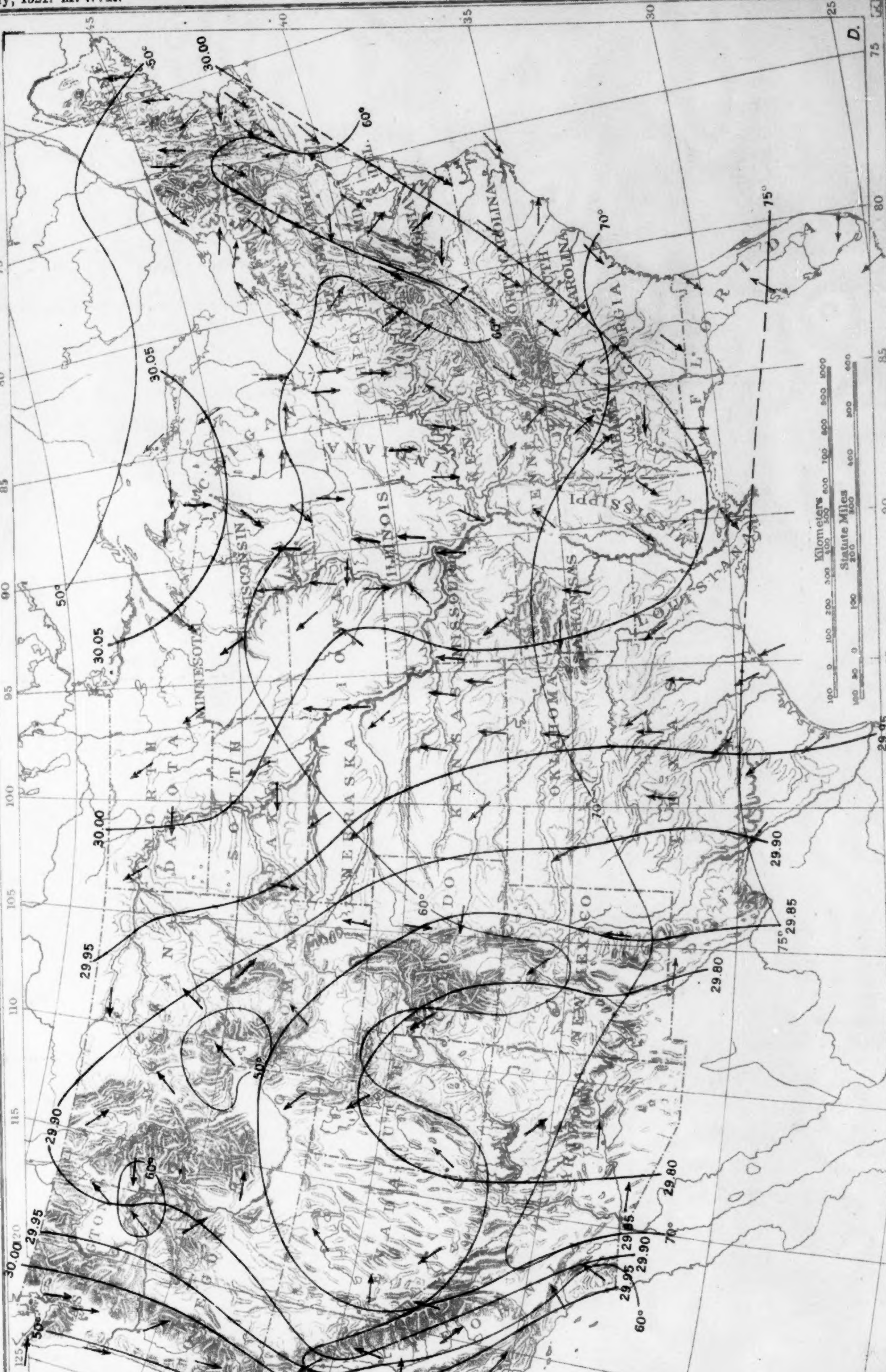


Chart IX. Weather Map of North Atlantic Ocean, May 5, 1921.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, May 5, 1921.
(Plotted by F. A. Young.)

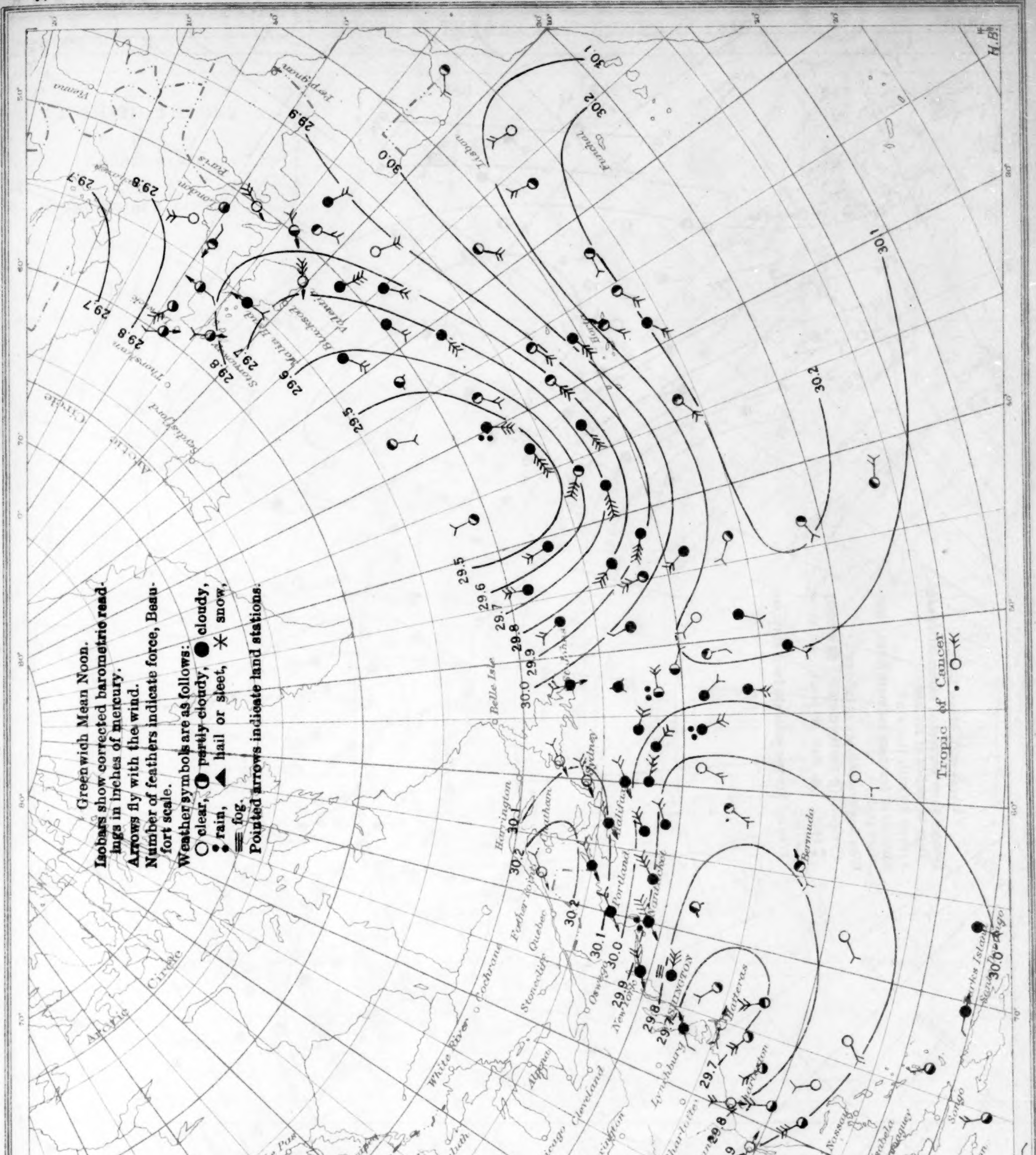
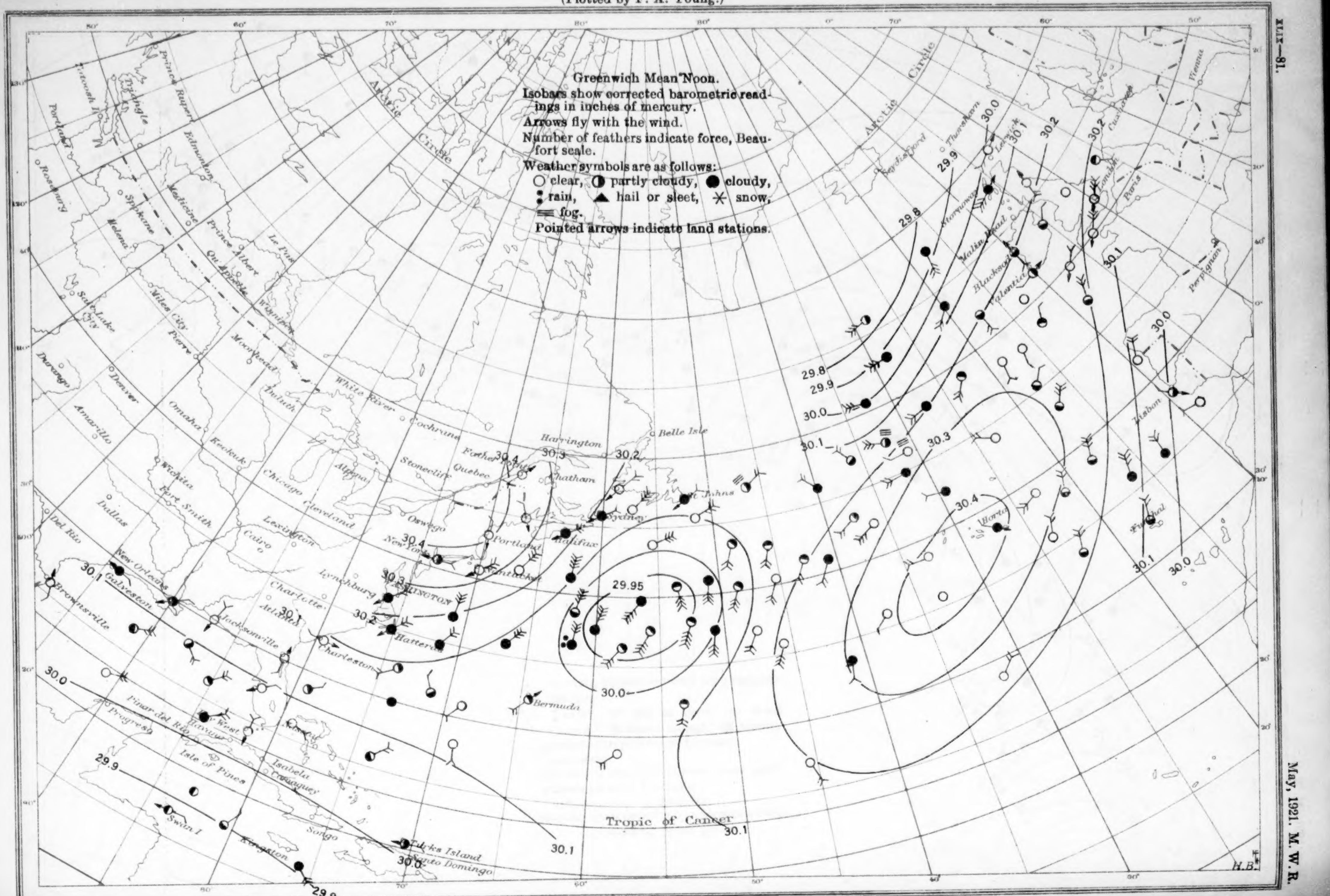
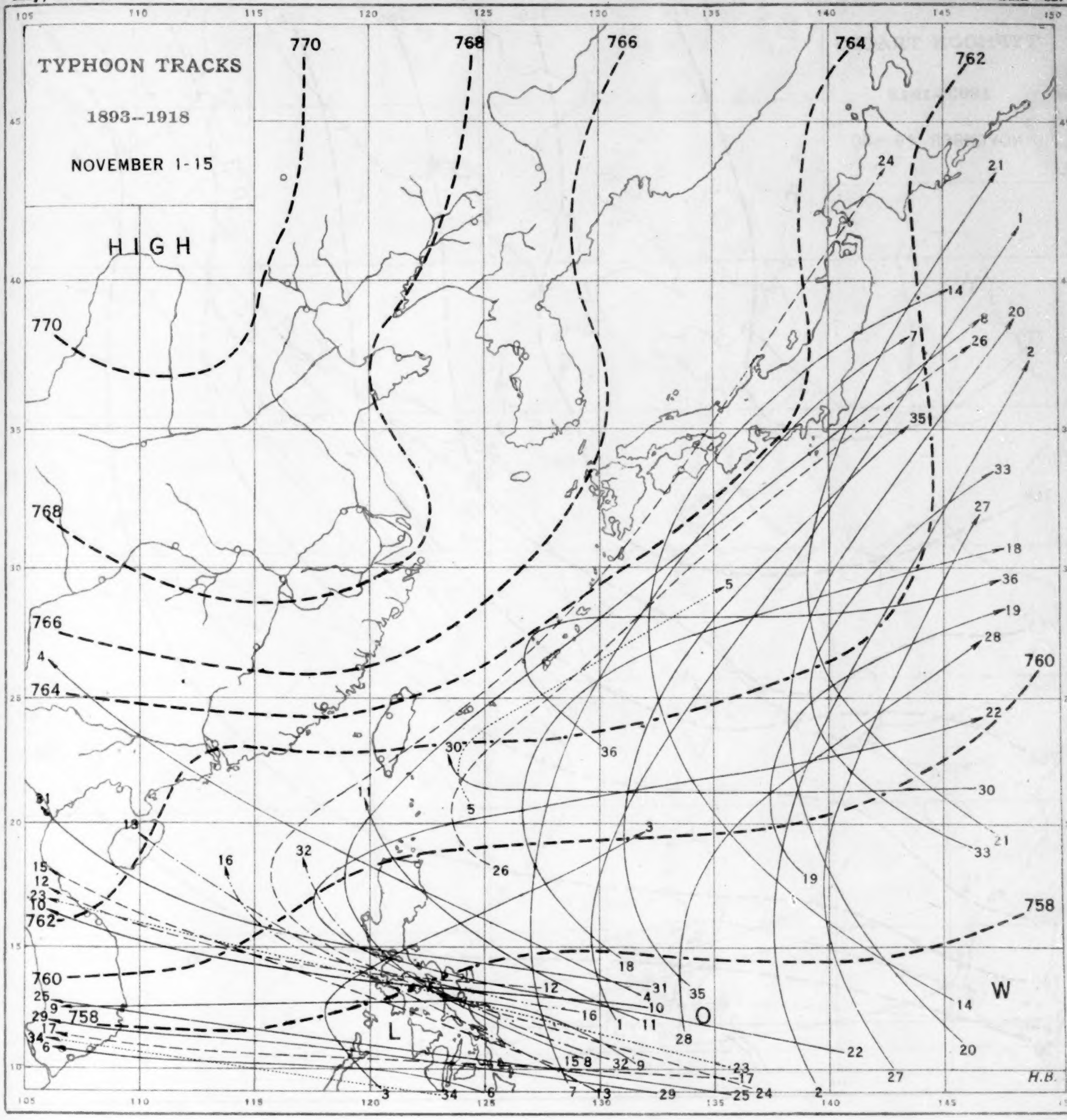


Chart X. Weather Map of North Atlantic Ocean, May 24, 1921.

(Plotted by F. A. Young.)



TYPHOONS IN THE FAR EAST DURING 26 YEARS.

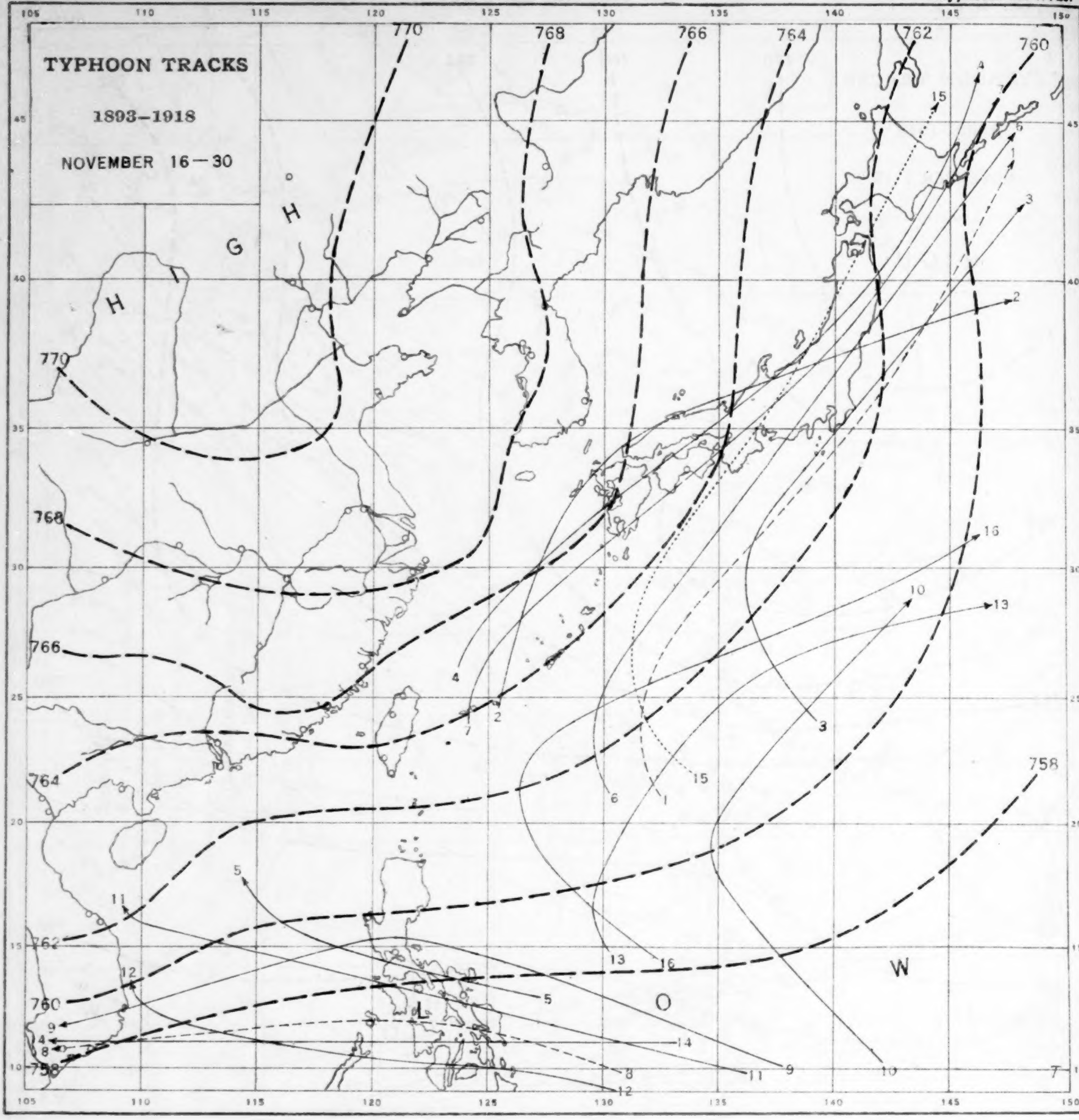


NOVEMBER.—*Two charts: 52 tracks; two instances every year.*

First fortnight: 1-15.—36 tracks.—The high pressures of the continent have succeeded to expulse the typhoons from the Sea of Japan, the Eastern Sea and the Channels between Formosa and Luzon. No case has been recorded to the NW of a line running from the Pratas to the S. point of Hokkaïdo. It may be noted that the isobar 764^{mm} forms again a kind of frontier against the oceanic storms, from Swatow to Formosa, thence to the Van Diemen Strait and across Central Japan.

The point from which the trajectories are issued has retired to the low latitudes, about 5° to 8°, to the SW of Yap. Not a few tracks are recurving on the Pacific to the S of Japan, with a marked preference for the N Marianas and the Bonin. On the China Sea there is rather an increase of activity, it is like the last battlefield of the typhoons, divided in two columns, the one advancing from the Visayas to the coast of Annam, across the Paracels, the other travelling from Mindanao or Palawan to the shores of lower Cochinchina, keeping their course between latitudes 9° and 12°.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director, Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]

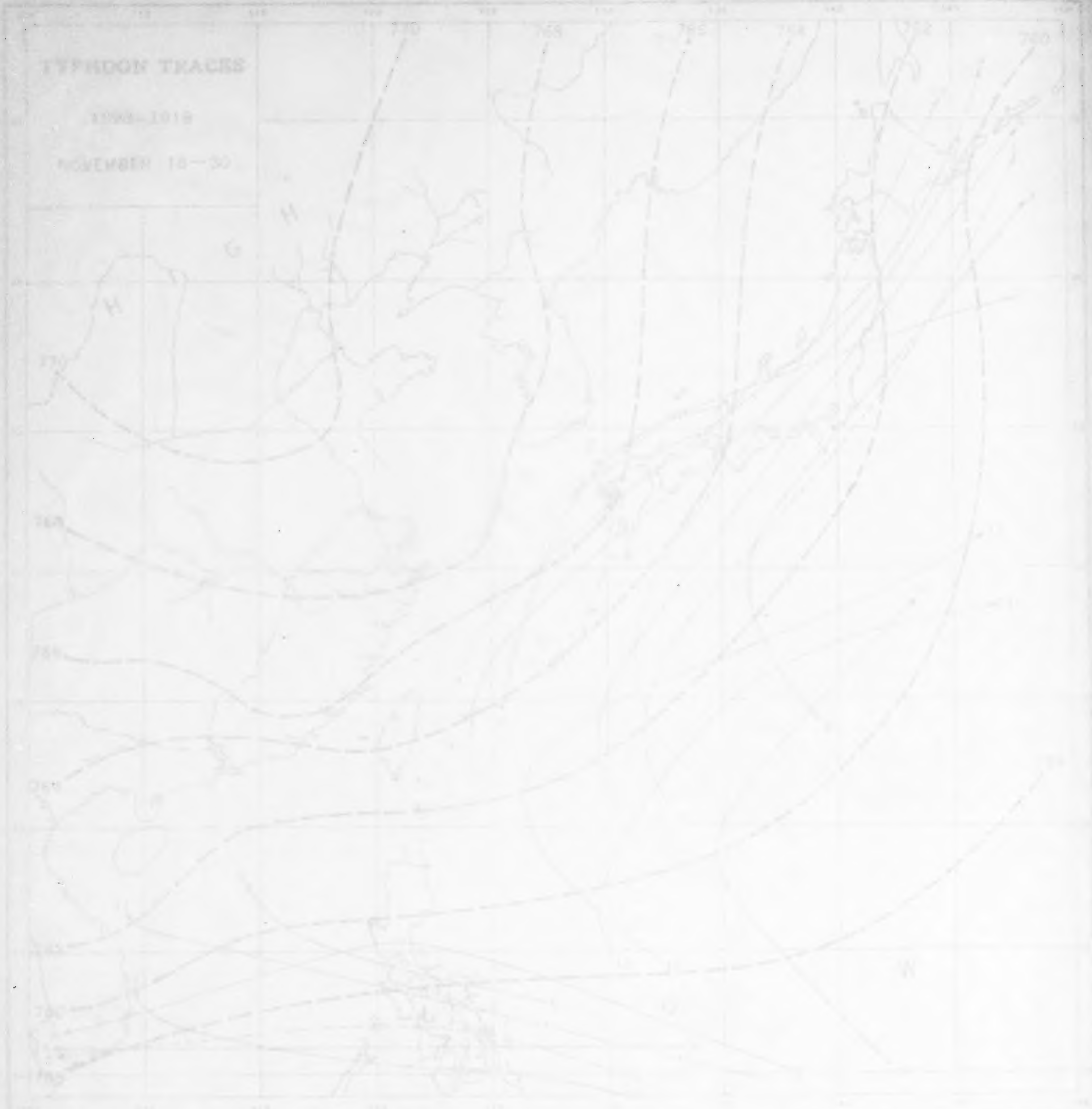


NOVEMBER.—*Two charts: 52 tracks; two instances every year.*

Second fortnight: 16-30.—16 tracks.—We find ourselves under the full influence of the high pressures emanating from the great asiatic anticyclone, and consequently the winter monsoon has established its reign along our coasts. A few trajectories are still found between Japan and the Bonin. Three times Japan has been crossed from end to end, but such depressions, born between Formosa and the Loochoos appear to be a kind of hybrid storms having a bond with the family of the continental depressions, rather than real typhoons.

On the China Sea too, the storms are gradually disappearing; and those which cross the 15th parallel meet soon with their death. The remaining energy is concentrated in those centres which circulate along the 10th parallel, between the S. Visayas and Cochinchina; one of the last ones at least has followed distinctly a WSW direction, from Manila bay to Cape Padaran. Let us add however that the month is not a peaceful one, to the N. of the Formosa Strait, for if the typhoons have left the field, it remains open to the Continental depressions, and the monsoon, with its NW or NE gales is often very hard to the ships sailing against it from Hongkong to the northern ports.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]



NOVEMBER.—*Two charts:* 33 tracks; two isobaric maps.

Second fortnight: 16-30.—16 tracks.—We find ourselves under the full influence of the high pressures emanating from the great asiatic anticyclone, and consequently the winter monsoon has established its reign along the coasts. A few depressions are still found between Japan and the Bonin. Three times Japan has been crossed from end to end, but such depressions born between Formosa and the Loochoos appear to be a kind of hybrid storms having a bond with the family of the continental depressions rather than real typhoons.

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MAY, 1921.

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